RABBIT FEEDING FOR MEAT AND FUR

SECOND EDITION

by

F. C. AITKEN, B.Sc.

and

W. KING WILSON

TECHNICAL COMMUNICATION No. 12
COMMONWEALTH BUREAU OF ANIMAL NUTRITION
ROWETT INSTITUTE, BUCKSBURN, ABERDEEN, SCOTLAND

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Preface

In the last six or seven years the rearing of domesticated rabbits in the United Kingdom has experienced two powerful stimuli. The extension to Britain in 1954 of the myxoma virus and its rapid spread over the whole country led to the disappearance of rabbit meat from the butchers' shops in the towns where most of the carcases were sold. The National Food Survey Committee reported that by September of that year rabbit meat was making no appreciable contribution to the national diet. In the same period the revolution that has taken place in production of poultry by the development of the broiler industry has shown that there is a demand for white meat which, with careful attention to economics, can in practice be satisfied. In this connection the National Food Survey Committee has given the results of its findings as showing that in 1959 consumption of poultry was 170 per cent of the amount for 1957. It is natural that in a market expanding at that rate the competitive possibilities in production of rabbit meat should arouse interest commercially.

In the keeping of stock under such highly artificial and competitive conditions the importance of correct feeding needs no emphasis. As Mrs. Aitken has found in her examination of the literature, knowledge of rabbit nutrition is not nearly so complete as is that of poultry nutrition. In this new edition of "Rabbit Feeding for Meat and Fur" she and Mr. Wilson have summarised what information is available and have shown where gaps exist. Their compilation will, it is hoped, be of use to scientific workers interested in the rabbit as a biological tool and to producers interested in the commercial value of its flesh and fur.

D. Harvey

June 1961

RABBIT FEEDING FOR MEAT AND FUR

Introduction

In a brief review of the domestic rabbit industry the Secretary of the British Rabbit Council (Sandford, 1957) lists France as probably the chief producer of domestic rabbit. There, during the last war, some 120 to 140 million rabbits were produced annually. The rabbits are mostly kept in small units with fur the primary concern and much of the meat is consumed by the producers. Nevertheless many carcases are marketed; a recent estimate (Anon., 1960) puts carcase production at 70 million. In many other European countries the industry follows the French pattern with Italy coming close in the number of rabbits it produces. In the United States production of domestic rabbits is much less—it was estimated to be about 24 million rabbits in the peak year of 1944 (National Research Council, Committee on Animal Nutrition, U.S.A., 1954)—but that country led the way in the development of rabbit rearing in large units primarily for meat. Particularly in Southern California an industry has developed mainly for the production of young rabbits for slaughter at age about 8 weeks and weight about 4 lb, with the sale of pelts as a secondary concern. It is estimated that between 50 and 60 million pounds by weight of domestic rabbit meat is produced annually in the United States (Smith, Donefer and Mathieu, 1960). In Britain there has been in the past some rearing of rabbits for meat and fur, usually to 3 or 4 months of age if primarily for meat or to about 7 to 9 months if primarily for fur. Recently there has been a sudden development on the American pattern of large-scale rearing of rabbits for meat.

There is very little scientific information on the feed requirements of rabbits. Recommended allowances are based largely on the results of practical experience; so, in this technical communication presentation and discussion of recommended rations precedes a review of the literature on nutrient requirements.

No attempt has been made to discuss the possible effect of nutrition on resistance to infection. The results of experimental work, largely on laboratory animals other than the rabbit, are inconclusive and indeed controversial. Nevertheless the high morbidity and mortality in rabbit stock in large-scale production cannot be ignored. In an experiment by Templeton (1952) 87 per cent of the does were replaced on a yearly basis, largely because of metritis, pneumonia, failure to conceive, sore hocks, scabby nose and abcesses. In commercial herds in Southern California, the annual replacement of does averaged at that time about 100 per cent. In the same study Templeton reported mortality of 22 to 24 per cent in groups of young rabbits reared for slaughter at 8 or 9 weeks and said this was comparable to that in commercial herds. Causes of death were enteritis, pneumonia and abscesses, and occasionally excessive heat, malocclusion and accidents. In a study of the effect of age of weaning on weight gain in rabbits in Australia, Menzies (1959) reported that deaths

up to 16 weeks in 3 experimental groups were 21·6, 9·0 and 23·5 per cent. These figures were considered not unduly high. Obviously such a rapid turnover of breeding stock and high mortality of the young must greatly increase cost of production and investigation of causes might be profitable.

General principles of feeding

In rearing of rabbits commercially for meat and fur the approach to the problem of planning rations is the same as for other livestock reared for meat or wool. The digestibility of feeds of known crude composition is estimated and the energy value of the diet and the amounts of protein, which in mixed rations give the required level of production, are established. These amounts of energy and protein may be obtained from different combinations of feedingstuffs, care being taken to choose a mixture likely to supply the animals' needs for minerals and vitamins. Consideration must be given also to the amount of fibre likely to be acceptable and to the general palatability of the ration offered. Finally, in modern livestock management attention is given to the possible benefits to production which may accrue from the incorporation of antibiotics in the ration.

Digestion

Herbivorous mammals have a greater relative capacity of the alimentary tract than carnivores, the ruminant because of its large, four-compartment stomach, the non-ruminant because of its large caecum and colon. Microbial digestion of starch and cellulose in the stomach of ruminants and in the large intestine of other herbivora is accompanied by synthesis of microbial substances. The products of synthesis in the rumen are made available to the host by subsequent digestion but in the non-ruminant microbial digestion follows peptic and tryptic digestion of feed and most of the synthesised material within the microbial cell is excreted. For a more detailed account of microbial digestion in herbivora reference should be made to the review by Baker, Harris, Phillipson, McNaught, Smith, Kon and Porter (1947). Such products of microbial synthesis are not entirely lost to the rabbit because of its habit of coprophagy. The domestic rabbit passes hard faeces during the day and soft faeces at night. The night faeces, which are low in fibre and high in protein content compared with day faeces, are eaten direct from the anus (Morot, 1882; Madsen, 1939; Taylor, 1939, 1940; Eden, 1940; Frank, Hadeler and Harder, 1951) and putting rabbits on wire trays does not prevent coprophagy. In rabbits free to practise coprophagy utilisation of dry matter and protein in the diet is more efficient than in animals collared or stanchioned to prevent it (Eden, 1940; Kulwich, Struglia and Pearson, 1953; Huang, Ulrich and McCay, 1954). It was at first thought that coprophagy might improve digestion of fibre. The title of Madsen's (1939) letter to *Nature* was "Does the rabbit chew the cud?". But it is not the high-fibre day faeces which are eaten and Thacker and Brandt (1955) showed that with a diet high in roughage consumption of faeces did not influence digestion of cellulose or other carbohydrate although with a purified diet

with less roughage digestion of all constituents was improved by coprophagy.

Olcese and Pearson (1948) obtained improved growth in rabbits on a purified diet when the casein content was increased from 10 to 20 per cent but no improvement resulted when an equivalent amount of urea was given instead of the extra casein. The rabbits were free to practise coprophagy. They concluded that the rabbit could not utilise urea N for the synthesis of protein.

Comparative digestibility trials with rabbits and ruminants given dried grass (Watson and Godden, 1935; Crampton, Campbell and Lange, 1940; Neseni and Scheven, 1958), fresh grass (Watson and Horton, 1936; Ellis, Matrone and Maynard, 1946), marrowstem kale (Watson and Horton, 1936), lucerne hay and silage (Nehring and Schramm, 1939), lucerne and sericea hays (Hawkins, 1957), show that the fibre of roughage is less well digested by rabbits than by ruminants, but that there is less difference in digestibility of other nutrients and little in digestibility of crude protein. An exception is the finding of Neseni and Scheven (1958) that with green clover all digestion coefficients were higher for rabbits than for sheep. There is evidence that the rabbit digests all the nutrients in fresh or dried beet tops better than do sheep (Neseni and Scheven, 1958) and for sunflower seed meal Nickisch (1952) found the same to be true although differences were small except for fat.

The digestibility of feedingstuffs by rabbits has been studied by several workers and the results have been collected in tables in Swedish with English subtitles (Jarl, 1944). These show that the rabbit digests fibre of dry roughage and silage much less efficiently than that of green feed, roots and tubers. The effects of drying on digestibility of pasture forage has been investigated by Miller, Waugh and Matrone (1954) who gave the dry and green roughage to rabbits in amounts supplying the same dry matter. They found that artificial drying at 60°C significantly reduced the digestibilities of protein and lignin of ladino clover, tall fescue and orchard grass, but after drying the crude fibre of the two grasses was more digestible. The digestibility coefficients of crude fibre of dry and green ladino clover were 2 or 3 times those of the grasses.

Jarl's compilation shows surprising variation in the coefficients of digestibility of crude fibre of cereals with the source of the information. According to the principal American study (Voris, Marcy, Thacker and Wainio, 1940) none of the fibre of oats is digested while other workers report from 10 to 27 per cent as being digested. The American coefficient of digestibility of fibre in barley is only 12 per cent while other coefficients range from 25 to 72 per cent. In wheat the coefficient of digestibility of fibre is 28 per cent according to the American study and 91 per cent according to a German study.

We know of no parallel to those variations in ruminant digestibility trials although the method used is broadly the same. A cereal is given with roughage of known digestibility and the digestibility of the cereal is calculated by difference from the observed digestibility of the mixture of roughage and cereal. In European digestibility trials with rabbits the roughage is usually meadow hay, the cereal is often given as meal and the

rabbits are usually adult. In the American study the roughage was alfalfa hay, the cereals were given whole and the New Zealand White rabbits weighed about 4 lb and hence would have been about 8 weeks old. Investigation of such differences and other possible causes of variation in digestibility of fibre of cereals is needed for the best use to be made of the available data on digestibility.

The effect of grinding green wheat and alfalfa on the digestibility of diets consisting of oats 60, green wheat or alfalfa 30, bran 9 and salt 1 per cent was studied by Heller, Wall and Briggs (1941). The crude fibre of the diet containing green wheat was digested better when the green wheat was coarsely ground than when finely ground. Grinding the alfalfa had little effect on the digestibility of crude fibre of the alfalfa ration. According to Gasnier, Archambaud and Leroy (1941) crushed bran and lucerne were no better in feeding value than whole. But Brozzetti (1941) reported that less hay meal than long hay was required per kg gain in liveweight by young rabbits on a diet of lucerne hay or hay meal and bran. Donnelly and Hawkins (1959) found that although there was little difference in crude fibre content between coarse- and fine-stemmed sericea lespedeza, digestibilities of crude fibre, nitrogen-free extract and total carbohydrates were significantly higher for the fine-stemmed types. Differences in digestibilities of crude protein and cellulose were not significant.

The following table (Table 1) gives coefficients of digestibility of some rabbit feeds. Those given by Schürch (1949) are average or selected values obtained from the literature. The others are the results obtained by the authors cited in the table. For a more detailed list of coefficients reference should be made to the table of Jarl (1944) and to the summary table of Schürch (1949) which is available also in Italian (Tacci, 1952).

The effect of the amount of crude fibre in the diet on digestibility of other nutrients has been studied by several workers (Prjanischnikow and Tomme, 1936; Mangold, Columbus and Hock, 1937; Axelsson, 1942; Abgarowicz, 1948; Crasemann, 1952; Eriksson, 1952; Barboriak, 1953; Behm, 1954). Interpretation of the results is complicated by the fact that the addition of straw or sawdust to increase the fibre content of the diet reduces the protein content, a change which of itself would affect digestibility of protein. Eriksson (1952) used hay and oats to increase the fibre content of the ration. He eliminated the effect of difference in protein content by calculating partial coefficients of correlation and found that there remained a significant depressing effect of crude fibre on digestibility of protein. A similar conclusion was reached by Glover and Duthie (1958) from equations derived from direct digestibility trials reported by Voris *et al.* (1940). However, Glover and Duthie pointed out that the fibre content of normal rations would have little depressing effect on digestibility of protein.

We have calculated that the crude fibre content of dry matter in recommended rations ranges from about 10 to 26 per cent.

Choice of feed and methods of feeding

Almost any of the green feeds, roots, hays and concentrate feedingstuffs used for larger domestic animals may be given to rabbits. In addition there

Table 1

Coefficients of digestibility of some rabbit feeds

	Crude protein	Crude fat	Crude fibre	Nitrogen-free extract	Reference
Bluegrass	74	41	13	41	Voris *et al.*, 1940
Clover, green	74	73	65	80	Neseni and Scheven, 1958
dried	73	44	34	68	,, ,, ,,
Ladino clover, green	87	54	65	89	Miller *et al.*, 1954
dried	84	55	64	86	,, ,, ,,
Alfalfa (lucerne), green	86	70	54	81	Schürch, 1949
Orchard grass, green	80	43	28	42	Miller *et al.*, 1954
dried	75	42	37	48	,, ,, ,,
Sudan grass	68	49	27	64	Voris *et al.*, 1940
Tall fescue, green	84	53	23	40	Miller *et al.*, 1954
dried	81	52	26	41	,, ,, ,,
Mixed grasses with clover, green	77	46	49	66	Watson and Horton, 1936
dried	62	26	26	56	Watson and Godden, 1935
Clover hay	63	62	20	67	Voris *et al.*, 1940
Alfalfa (lucerne) hay	72	16	18	63	,, ,, ,,
Meadow hay (good)	50	45	33	55	Schürch, 1949
Nettle hay	96	32	42	79	Brüggemann, 1937
Oat hay, green	61	54	10	36	Voris *et al.*, 1940
Timothy hay	47	44	11	51	,, ,, ,,
Vetch hay	78	63	11	72	,, ,, ,,
Wheat hay, green	78	50	22	53	,, ,, ,,
Oat straw	30	30	25	35	Schürch, 1949
Artichoke tops	68	59	56	77	Stute, 1953
Beet tops, fresh	83	72	89	92	Neseni and Scheven, 1958
dried	67	69	69	85	,, ,, ,,
Cabbage	99	83	88	103	Voris *et al.*, 1940
Gout weed	73	54	82	85	Nehring and Schramm, 1939
Marrowstem kale	86	72	55	88	Watson and Horton, 1936
Sow thistle, green	75	63	77	93	Nehring and Schramm, 1939
Fodder beets	66	80	100	96	Schürch, 1949
Carrots	86	79	56	98	Voris *et al.*, 1940
Celery	77	91	93	99	,, ,, ,,
Potatoes, steamed	68	85	83	98	Schürch, 1949
Turnips	91	103	82	101	Voris *et al.*, 1940
Barley	75	89	28	91	Schürch, 1949
	85	106	12	89	Voris *et al.*, 1940
Maize	81	92	45	92	Schürch, 1949
	84	93	146	92	Voris *et al.*, 1940
Oats	81	92	19	79	Schürch, 1949
	79	98	−2·4	79	Voris *et al.*, 1940
Sorghum	72	96	103	91	,, ,, ,,
Rye	69	81	25	92	Schürch, 1949
	79	82	54	93	Voris *et al.*, 1940
Wheat	83	92	28	95	Schürch, 1949
	85	100	28	97	Voris *et al.*, 1940
Wheat bran	83	77	24	65	,, ,, ,,
Burdock seed meal	90	97	33	58	Nickisch, 1950
Groundnut cake	91	101	49	96	Voris *et al.*, 1940
Linseed oil cake	86	99	20	81	,, ,, ,,
Mustard seed meal	75	100	32	87	Nickisch, 1950
Rapeseed cake	76	95	64	70	,, ,,
Sesame cake	91	101	73	84	Voris *et al.*, 1940
Soya bean oil cake	90	96	52	96	,, ,, ,,
Fishmeal	75	100	—	48	Schürch, 1949
Dried bread	95	98	—	101	Voris *et al.*, 1940
Kitchen waste	70	80	50	80	Schürch, 1949

are many vegetables and weeds which are suitable and even silkworm pupae have been used (Elenek, 1954). Some plants are not acceptable and some are toxic. Most of those come into the category of weeds, the most harmful of which are listed by Pickard (1941) and Sandford (1957). Others are sugar beet tops (Wilson and Downham, 1932), onion (Baldissera-Nordio, 1952*a*,*b*, 1953), raw kidney beans and hyacinth beans (Jaffé, 1950), bran affected with rust or smut (Bidone, 1933), cottonseed oil cake or meal (Voris *et al.*, 1940; Holley *et al.*, 1955). There is also the risk of goitre associated with excessive consumption of cabbage (McCarrison, Sankaran and Madhava, 1933; Downs, 1936; Bonadonna and Pozzi, 1957) and of reproductive failure with soya bean forage or hay (Kendall, Salisbury and Vandemark, 1950; Kendall, Hays and Rolleri, 1954; Magee and Matrone, 1958). Fishmeal from fat fish, although not harmful, is usually avoided for fear of tainting the meat. White-fish meal, up to a level of 10 per cent in mash, has been found not to taint rabbit meat (Wilson and Botham, 1933–34). According to Hagelin (1935) turnips, cabbage and cauliflower should not be used in finishing rations because of the danger to flavour. There is some evidence that white clover in lawn mowings or in hay may be a cause of bloat (Wilson, 1954). The commonest type of ration, on the Continent of Europe at any rate, consists of hay, roots and concentrates in winter and green feed, with or without hay, in summer. In America dry diets of alfalfa hay and concentrates without any fresh green or succulent feed are commonly used. The choice of feed will depend on availability, quality and cost. The adult male rabbit or non-pregnant female can maintain bodyweight in summer on fresh green feed of good quality, such as meadow grass, timothy, clover and lucerne (Voinov, 1933) or on a mixture of fresh clover and clover hay (Hagelin, 1935; Page, 1942). Weight can be maintained also on a ration of alfalfa hay alone (Adolph, Macdonald, Yeh and Lofgreen, 1947). From conception, in lactation and during the growth of the young concentrates are required to give the high levels of production needed in commercial rabbit rearing. Although concentrates may not be necessary in maintenance rations if the green feed or hay is of good quality most recommended rations include some concentrates. In the rations described in the following pages concentrates usually contribute about one-third or half of the total energy allowed for maintenance, pregnancy and growth. In rations recommended for lactation concentrates may supply over 80 per cent of the total (National Research Council, Committee on Animal Nutrition, U.S.A., 1954). Nikitin and Lipatova (1956) found that 17 to 22 per cent of the energy supplied as concentrates sufficed in summer rations and 35 to 40 per cent in winter rations gave satisfactory growth of sucking young. The proportion of energy supplied by concentrates in the ration recommended by Dunkel (1955) appears to be of the order of 30 per cent and that of Schürch's ration about 46 per cent. Since individual concentrates vary widely in their content of digestible protein it does not serve any useful purpose to make generalisations about desirable proportions of concentrates in rations.

Pelleting the concentrates eliminates wastage but early attempts to feed rabbits on pelleted rations failed on account of impaction paralysis (Christian, 1935–36) which may be obviated by provision of green feed

and water. Later it was found that a ration of bran 15, sugar beet pulp or barley meal 20, groundnut meal 15, linseed cake 10, dried meat-and-bone meal 8, dried grass meal 30, calcium carbonate 1 and sodium chloride 1 per cent made up in pellets gave good growth (Bruce and Parkes, 1946) and good reproduction (Bruce, 1947) provided an ample supply of water was available. Fresh green feed was not necessary. The percentage composition of the pelleted diet, as calculated by Bruce and Parkes, is given in Table 2.

Table 2

Chemical composition of pelleted Diet 18 (Bruce and Parkes)

	with barley meal	with sugar beet pulp
Digestible crude protein	16·5	16·0
Fat	4·6	4·3
Soluble carbohydrate	33·7	32·8
Fibre	6·7	9·4

This pelleted diet of Bruce and Parkes, known as Diet 18, was used for feeding rabbits and guineapigs, but recently evidence has accumulated that its use may be attended by certain troubles, loss of condition and reproductive failure and in some instances muscular dystrophy (Short and Gammage, 1959). Short and Gammage devised a new pelleted diet to take the place of Diet 18 and were careful to exclude feeds prone to become rancid such as groundnut cake, linseed cake meal, bone meal and barley meal. The diet which they called Diet SG1 contained best white-fish meal (67% protein) 10, grassmeal (18% protein) 20, bran 40, Sussex ground oats 12 and wheat middlings 18 per cent.

The protein content of samples of the diet was 22·3 per cent. We have used published values for composition and digestibility of feeds similar to the ingredients of Diet SG1 to obtain an approximate estimate of the nutritive value of the diet (Table 3).

Table 3

Calculated percentage composition of pelleted Diet SG1

Ingredient	Amount g	Water g	Crude protein g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Best white-fish meal	10	1·0	6·0	—	4·5	28
Grassmeal	20	1·9	4·2	4·3	2·6	42
Bran	40	4·2	6·7	4·2	5·6	105
Sussex ground oats	12	1·5	1·3	1·3	1·0	34
Middlings (taken as bran)	18	1·9	3·0	1·9	2·5	47
	100	10·5	21·2	11·7	16·2	257

Digestible crude protein per thousand kcal EDF 63 g
Nutritive ratio 1 : 1·8
Percentage crude fibre in dry matter 13

The new diet had protein of higher biological value for rats than Diet 18. Short and Gammage found that condition and reproductive performance of

rabbits on Diet SG1, supplemented with hay, were better than with Diet 18. This has been the experience also at the Rowett Research Institute where Diet SG1 supplemented with vitamins, and for pregnant and lactating does, with vitamins and hay, has been much more satisfactory than was Diet 18, as stock diet for a colony of Chinchilla Giganta. The vitamins, as a premix, are added to the diet at the rate of $\frac{1}{2}$ cwt to 2 tons Diet SG1. The premix contains per cwt 16,000,000 I.U. vitamin A, 4,000,000 I.U. vitamin D_3, both stabilised, 32,000 mg riboflavin and 100,000 mg vitamin E (Clarke, 1961).

In the United States National Research Council report on requirements of rabbits a pelleted diet used by Kellogg, Templeton and Suitor (1949), with alfalfa hay, is given as an example of a diet suitable for rabbits. The ingredients are listed in Table 4.

Table 4

Pelleted diet (National Research Council)

Soya bean oil meal	18
Linseed oil meal	4
Alfalfa (lucerne) meal	40
Wheat bran	15
Barley grain, ground	18
Oats grain, ground	4
Salt	1
	100

They include linseed oil meal and barley meal, two of the ingredients avoided by Short and Gammage (1959) because of the danger of rancidity, but we have no report of ill effects from their use. A report from Maryland of nutritional muscular dystrophy in rabbits fed on "one of the nationally known rabbit pellets" does not, unfortunately, give the name or composition of the pellets. When they were supplemented by roots and greenstuffs there were few further instances of the condition (Innes and Yevich, 1954). According to another report (Milman and Milhorat, 1953) Rockland Pellet diet was found to be so low in vitamin E as to produce muscular dystrophy which was cured by administration of vitamin E.

Methods of feeding are discussed by Sandford (1957), Templeton and Kellogg (1959) and Wilson (1959). One method which was used by the breeder of rabbits primarily for fur was to leave the hay in racks for the rabbits to eat to appetite and to supply the remainder of the food in two feeds for adults and in three feeds per day for young rabbits. This method has the advantage of preventing breeding bucks and the does which have not yet conceived from getting too fat and rabbits which have to be fed for several months until the fur is suitable for marketing from eating too much concentrates. Another method, well suited for lactating does with young destined for slaughter at an early age for meat, is to use hoppers with separate compartments for each different feedingstuff and from which the rabbit may eat at will. Such a system saves time and labour and is said to produce fryer rabbits of uniform quality. It may be used for bucks and young does if the diet is a suitable pelleted feed but with other diets care must be taken to prevent such stock from getting too fat.

Short (1960) has described an automatic rabbit battery with cages around which runs a rail carrying containers of feed and water. The rabbits are on wire mesh and excreta which fall through to a sealed floor are swept away by devices attached to the continuously moving carriages. A study of weight gained over 18 weeks by three comparable groups of six rabbits on a pelleted diet, one in an ordinary cage with hopper and two groups in the battery, one given hay and the other not, showed no significant difference between the groups.

Recommended rations for maintenance and production

In this chapter we have described some recommended rations and tabulated our estimates of the amounts of water, crude fibre, digestible crude protein and energy in some of them. The analytical and digestibility data used in these calculations are given in the appendix. Values for energy of digested feed (EDF), which is the heat of combustion of the feed, less the heat of combustion of the undigested materials in the faeces, were measured by calorimetry (Voris *et al.*, 1940) or they were calculated by us by applying to the digested nutrients of the feeds appropriate factors given by Merrill and Watt (1955) for heats of combustion of protein, carbohydrate and fat. Nutritive ratios were calculated as energy from digestible crude protein : energy from other digestible nutrients. For the calculation of nutritive ratios of mixed rations 1 g digestible crude protein was taken as having an energy value of 5·65 kcal. Other calculated values were the amount of digestible crude protein per thousand kcal EDF, and where possible, per kg bodyweight per day, and the percentage of crude fibre in the dry matter of the rations.

Maintenance

A series of rabbit feeding tests with fur and wool breeds was made by King Wilson at Harper Adams College (Wilson, 1927–28; 1928–29*a*,*b*,*c*; 1930; 1932). For maintenance, two feeds were given daily; dry mash and either poor hay or green feed in the morning and grain and green feed in the afternoon. In winter roots partly replaced the greens. Different proportions of dry feed to green (or root) were used. The general recommendation arising from these trials for the maintenance of small to medium

Table 5

Composition of dry mash

(Harper Adams College)

Feed	Amount	Water	Crude fibre	Digestible crude protein	Energy of digested feed (EDF)
	g	g	g	g	kcal
Yellow maize	40	5·6	0·8	3·4	146
Sussex ground oats	40	4·8	4·2	3·4	116
Wheat bran	10	1·0	1·0	1·4	26
White-fish meal	10	1·0	—	4·5	28
Total	100	12·4	6·0	12·7	316

sized rabbits (about 2·5 kg) was 1 ounce of dry mash, ¾ ounce of oats, 2 ounces of hay and 4 to 12 ounces of green feed or roots daily. When green feed was plentiful the amount of dry feeds was reduced and that of greens increased to between 8 and 15 ounces. When green feed was scarce the hay allowance was increased. The calculated nutritive value of the dry mash and the recommended maintenance ration are shown in Tables 5 and 6, respectively.

Table 6

Maintenance ration for small to medium sized rabbits (about 2·5 kg)
(Harper Adams College)

Feed	Amount oz	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Dry mash	1	28	3·5	1·7	3·6	88
Oats	¾	21	2·5	2·2	1·8	61
Hay	2	57	7·1	14·1	4·6	110
Greens or roots	4	114	100·3	2·3	1·7	45
Total		220	113·4	20·3	11·7	304
or						
Greens or roots	12	342	300·9	6·9	5·1	135
Total		448	314·0	24·9	15·1	394

Digestible crude protein per thousand kcal EDF 38 g
Digestible crude protein per kg bodyweight about 4·7 to 6·0 g
Nutritive ratio 1 : 3·6
Percentage crude fibre in dry matter 19

In the above calculation the hay was taken as clover hay and the greens or roots portion was taken as ⅔ marrowstem kale, ⅓ turnip.

The fishmeal and cereal types of mashes have been discontinued at the Harper Adams College with the advent of the fishmeal and cereal pelleted Diet SG1 already described. The use of a complete pelleted ration saves the labour associated with the provision of fresh green feed.

The Swedish rations described by Hagelin (1935) are based on a maintenance requirement of 0·08 feed unit for a rabbit weighing 3 kg. In summer a ration of green feed only is given. Suggested daily alternatives supplying 0·08 feed unit are 0·560 kg clover at beginning of flowering, 0·600 kg lucerne at beginning of flowering or 0·520 kg clover-grass mixture. These amounts are calculated by Hagelin to supply, respectively, 9·52, 12·60 and 7·80 g digestible protein, or 2·6 to 4·2 g per kg liveweight daily. In winter rations of hay or straw, concentrates and roots are given. Examples of winter rations are given below with our estimates of their nutritive value. Hagelin used figures for mixed grass and clover hay, not pure clover hay, in calculating the nutritive value of rations with "clover" hay so we have taken the hay as being medium quality meadow hay.

In the first plan oats and drinking water are given in the morning, hay and fodder beet in the evening. In the second, cod liver oil may be given with

Table 7

Winter ration with fodder beet
(Hagelin)

Feed	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
"Clover" hay	85	12·3	21·2	4·7	134
Oats	40	4·8	4·2	3·4	116
Fodder beet	125	106·8	1·1	0·9	69
	250	123·9	26·5	9·0	319

Digestible crude protein per thousand kcal EDF 28 g
Digestible crude protein per kg bodyweight 3·0 g
Nutritive ratio 1 : 5·3
Percentage crude fibre in dry matter 21

Table 8

Winter ration with oat straw
(Hagelin)

Feed	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Oat straw	60	8·4	23·8	0·7	64
Oats	60	7·3	6·4	5·2	175
Wheat bran	40	4·2	4·2	5·6	105
Soya bean meal	5	0·5	0·2	2·0	20
Carrots	50	43·8	0·6	0·6	22
	215	64·2	35·2	14·1	386

Digestible crude protein per thousand kcal EDF 37 g
Digestible crude protein per kg bodyweight 4·7 g
Nutritive ratio 1 : 3·8
Percentage crude fibre in dry matter 23

the oats which are given with the carrots in the morning. The bran and finely ground soya bean should be well mixed with 90 g water. This mash and the straw are given in the evening.

Hagelin also gives a winter ration with raw potatoes which consists of mixed grass and clover hay 70 g, oats 40 g and raw potatoes 75 g. Not having digestibility coefficients for raw potatoes we have not evaluated this ration. According to Hagelin's estimate the potato ration contains just a little less digestible protein than the fodder beet ration. The oats and drinking water are given in the morning, the hay and potatoes in the evening.

Schürch (1949) gives an example of a winter ration to meet the estimated daily maintenance requirements of a rabbit weighing 3·5 kg. According to

Schürch's calculation the ration has a feeding value of 0·06 starch unit* and supplies 8·7 g digestible true protein and 49·7 g "ballast" or undigested residue. Our analysis of this diet is given below in Table 9.

Table 9

Winter ration for maintenance of 3·5 kg rabbit

(Schürch)

Feed	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Hay, medium quality	50	7·2	12·5	2·8	79
Hay, very good	40	5·0	9·4	2·7	70
Fodder beet	100	85·4	0·9	0·7	55
Kitchen waste	100	88·0	1·1	1·3	39
Oats	30	3·5	3·3	2·6	88
	320	189·1	27·2	10·1	331

Digestible crude protein per thousand kcal EDF 30 g
Digestible crude protein per kg bodyweight 2·9 g
Nutritive ratio 1 : 4·8
Percentage crude fibre in dry matter 21

According to Romanovskii (1954) the daily maintenance requirements of an adult rabbit weighing 4 kg, 135 g feed units and 10 g digestible protein, are supplied by a winter ration of 150 to 200 g hay, 200 to 250 g succulent feeds such as carrots, beet, turnips, potatoes and 30 to 40 g concentrates such as oats, maize, barley, peas, soya bean and bran.

The estimates of nutrient requirements of rabbits published in the United States (National Research Council, Committee on Animal Nutrition, U.S.A., 1954) are based almost entirely on studies made at the Rabbit Experiment Station, Fontana, California with New Zealand White rabbits, a large breed used for commercial meat production. The report discusses the different kinds of feeds which rabbits eat but the examples given of adequate rations contain only hay and concentrates. The daily maintenance ration for does and bucks of average weight 10 lb (4·5 kg) is 0·22 lb clover hay and 0·16 lb of a mixture of equal parts oats, wheat and linseed oil meal pellets. This ration is estimated to supply 0·21 lb TDN and 0·04 lb (18·2 g) digestible protein daily. Our calculated nutritive value of this ration is given below (Table 10).

Lactation

At the Harper Adams College good results have been obtained with a mash of lucerne meal 5, wheat bran 7·5, barley meal 10, groundnut meal 7·5, linseed cake 5, meat-and-bone meal 4, minerals 1 part given with wilted greens and a small amount of potatoes or fodder beet. In a trial with five Brown does and their thirty young feed consumption per young, including the does' share in the first 4 weeks, was mash 1·83, greens 2·05

* 1 starch unit = 1 kg pure digestible starch

Table 10

Maintenance ration for does and bucks, average weight 10 lb (4·5 kg)
(National Research Council, U.S.A.)

Feed	Amount lb	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Clover hay	0·22	100	12·5	24·7	8·1	193
Oats	0·053	24	2·9	2·5	2·1	70
Wheat	0·053	24	3·6	0·5	1·8	84
Linseed oil meal pellets	0·053	24	2·6	1·9	7·6	82
		172	21·6	29·6	19·6	429

Digestible crude protein per thousand kcal EDF 46 g
Digestible crude protein per kg bodyweight 4·4 g
Nutritive ratio 1 : 2·9
Percentage crude fibre in dry matter 20

and potatoes or fodder beet 0·45 oz per day. These amounts multiplied by 6 give the amounts eaten by a doe and litter of 6. The nutritive value of the diet is shown in Table 11.

Table 11

Diet of Brown doe and litter of 6
(Harper Adams College)

Feed	Amount oz	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Mash	10·98	312	29·6	24·3	68·0	1005
Greens (as kale)	12·30	349	300·5	8·7	6·3	150
Potatoes	2·70	77	57·8	0·6	1·2	73
		738	387·9	33·6	75·5	1228

Digestible crude protein per thousand kcal EDF 61 g
Nutritive ratio 1 : 1·9
Percentage crude fibre in dry matter 10

Swedish rations for breeding does described by Hagelin with our estimates of their nutritive value are shown in Tables 12 to 14.

According to Hagelin these rations supply 0·35 feed unit, and respectively, 39·6, 41·6 and 38·9 g digestible protein.

The method of feeding the summer ration is to give hay to appetite in racks, and freshly cut clover morning and evening. In winter the morning feed consists of oats and carrots or oats and whole milk, the remainder of the ration being given in the evening. With the root ration, the hay and concentrates are made into a mash with 250 g water. With the milk ration no water is required but bran and oatmeal are well mixed with

Table 12
Summer ration for breeding doe
(Hagelin)

Feed	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Clover, fresh	1590	1276·8	52·5	33·4	938
"Clover" hay (as medium quality meadow hay)	300	43·5	75·0	16·5	474
	1890	1320·3	127·5	49·9	1412

Digestible crude protein per thousand kcal EDF 35 g
Nutritive ratio 1 : 4·0
Percentage crude fibre in dry matter 22

Table 13
Winter ration with roots for breeding doe
(Hagelin)

Feed	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Carrots	170	149·1	2·0	2·0	75
"Clover" hay (as medium quality meadow hay)	230	33·4	57·5	12·6	363
Oats	200	24·2	21·2	17·2	582
Bran	60	6·2	6·3	8·3	158
Soya bean meal	10	0·9	0·5	4·1	40
Fishmeal	10	1·0	—	4·5	28
	680	214·8	87·5	48·7	1246

Digestible crude protein per thousand kcal EDF 39 g
Nutritive ratio 1 : 3·5
Percentage crude fibre in dry matter 19

skimmed milk and given with hay. This ration is claimed to give optimum winter milk production by breeding does. In the root ration the carrots may be replaced by either 180 g fodder beet or 80 g potatoes plus fish liver oil to provide vitamins A and D or by 150 g marrowstem kale, 140 g silage or fresh pine or juniper to appetite.

Schürch (1949) described a winter ration with a feeding value of 0·13 starch unit providing 22·9 g digestible true protein and 66·6 g ballast, which would meet the needs of a doe of medium sized breed in the first month of lactation with 6 young. Our estimate of the nutritive value of the ration is presented in Table 15.

The National Research Council, Committee on Animal Nutrition, U.S.A. (1954) gives an example of a ration of alfalfa hay and concentrates

Table 14

Winter ration with milk for breeding doe
(Hagelin)

Feed	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
"Clover" hay (as medium quality meadow hay)	200	29·0	50·0	11·0	316
Oats	200	24·2	21·2	17·2	582
Bran	60	6·2	6·3	8·3	158
Whole milk	60	52·6	—	2·0	40
Skimmed milk	200	180·6	—	7·8	84
	720	292·6	77·5	46·3	1180

Digestible crude protein per thousand kcal EDF 39 g
Nutritive ratio 1 : 3·5
Percentage crude fibre in dry matter 18

Table 15

Winter ration for medium sized doe in first month of lactation with 6 young
(Schürch)

Feed	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Hay, good	100	12·4	23·5	6·8	175
Potatoes, steamed	200	150·0	1·6	3·2	190
Oats	70	8·3	7·8	6·0	206
Linseed cake	30	3·5	2·5	8·7	105
	400	174·2	35·4	24·7	676

Digestible crude protein per thousand kcal EDF 37 g
Nutritive ratio 1 : 3·8
Percentage crude fibre in dry matter 16

suitable for a pregnant doe weighing 10 lb (4·5 kg). The ration supplies 0·21 lb TDN, the same as the maintenance ration, and 0·05 lb (22·7 g) digestible protein as compared with 0·04 lb (18·2 g) in the maintenance ration. For a doe of the same weight, lactating, with a litter of 7, the amount of TDN is increased to 0·81 lb and the digestible protein to 0·24 lb (109 g). Our estimates of the nutritive value of these rations for pregnancy and lactation are shown in Tables 16 and 17.

Growth and fattening

While the young rabbit is dependent entirely on its mother's milk its diet, assuming the milk to be completely digested, provides, on the average, 58 g digestible protein per thousand kcal EDF and the nutritive ratio is on the average 1 : 2. Artificial feeding of baby rabbits on cow's milk mixtures

Table 16

Ration for pregnant doe of average weight 10 lb (4·5 kg)
(National Research Council, U.S.A.)

Feed	Per cent	Amount lb	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Alfalfa hay		0·25	114	13·0	35·2	14·7	216
Barley	38·5	0·14	24	3·5	1·5	2·2	77
Sorghum grain	38·5		24	1·6	0·5	2·1	84
Soya bean oil meal pellets	23·0		15	1·4	0·8	6·1	60
			177	19·5	38·0	25·1	437

Digestible crude protein per thousand kcal EDF 57 g
Digestible crude protein per kg bodyweight 5·6 g
Nutritive ratio 1 : 2·1
Percentage crude fibre in dry matter 24

Table 17

Ration for lactating doe of average weight 10 lb (4·5 kg) with litter of 7
(National Research Council, U.S.A.)

Feed	Per cent	Amount lb	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Alfalfa hay		0·24	109	12·4	33·7	14·1	206
Wheat	39	0·88	156	23·2	3·4	11·7	549
Sorghum grain	14		56	3·6	1·1	4·9	196
Soya bean oil meal pellets	47		188	17·5	9·4	76·7	752
			509	56·7	47·6	107·4	1703

Digestible crude protein per thousand kcal EDF 63 g
Digestible crude protein per kg bodyweight 23·9 g
Nutritive ratio 1 : 1·8
Percentage crude fibre in dry matter 11

has been accomplished by King Wilson at Harper Adams College and by workers elsewhere (Wiesner, 1952; Hills and Macdonald, 1956) but the procedure is of little practical importance for rabbit farming.

The time at which young rabbits begin to eat solid food may vary, for instance with the size of the litter. Davis (1957) found that on average young Chinchilla Giganta began to eat the mother's pelleted diet towards the end of the third week. Average consumption was 3 g per head. This increased to 10, 20 and 56 g by the fourth, fifth and sixth weeks when the average bodyweight was 1·1 kg. The feed consumed then increased weekly to a maximum of 160 g at 13 weeks of age.

The pelleted Diet SG1, which supports excellent growth, has a nutritive ratio of 1 : 1·8 and provides 63 g of digestible crude protein per thousand kcal EDF.

King Wilson recorded the average amounts of mash, greens, potatoes or fodder beet and hay eaten by young rabbits of Brown does over a 4-week period to 12 weeks of age. The mash was the same as in the lactation diet. Our estimate of the nutrients obtained per head per day is presented in Table 18.

Table 18

Average diet of Brown rabbits from age 8 to 12 weeks
(Harper Adams College)

Feed	Amount oz	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Mash	2·48	70	6·6	5·5	15·3	225
Greens (as kale)	3·36	95	81·8	2·4	1·7	41
Potatoes	1·57	45	33·8	0·4	0·7	43
Hay (as good meadow hay)	0·54	15	1·9	3·5	1·0	26
		225	124·1	11·8	18·7	335

Digestible crude protein per thousand kcal EDF 56 g
Digestible crude protein per kg bodyweight 15·0 g
Nutritive ratio 1 : 2·2
Percentage crude fibre in dry matter 12

This diet is almost identical with rabbit's milk of average composition in its nutritive ratio and content of digestible protein per thousand kcal EDF. Rabbits on this diet grew from an average weight of 2 lb 1·17 oz (0·9 kg) at 8 weeks to 3 lb 8·38 oz (1·6 kg) at 12 weeks. This is an average daily gain of 25 g.

Table 19

Ration for normal growth of rabbit of average weight 6·5 lb (3·0 kg)
(National Research Council, U.S.A.)

Feed	Amount lb	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Alfalfa hay	0·28	127	14·5	39·2	16·4	240
Oats 4 parts	0·16	29	3·5	3·1	2·5	84
Barley 4 parts		29	4·2	1·9	2·6	93
Soya bean oil meal pellets 2 parts		15	1·4	0·8	6·1	60
		200	23·6	45·0	27·6	477

Digestible crude protein per thousand kcal EDF 58 g
Digestible crude protein per kg bodyweight 9·2 g
Nutritive ratio 1 : 2·1
Percentage crude fibre in dry matter 26

Very similar to this Harper Adams ration in nutritive ratio and in amount of digestible crude protein in relation to energy of digested feed is the ration suggested by the National Research Council, Committee on Animal Nutrition, U.S.A. (1954) for normal growth from 4 to 9 lb, average 6·5 lb (3·0 kg).

Table 20 shows the daily fodder plan used at the Danish rabbit progeny testing station on Favrholm (Nielsen, Jensen and Hansen, 1958).

Table 20

Fodder plan
(Nielsen *et al.*)

Body-weight	Winter				Summer			
	Concentrates	Turnips	Hay	g feed units	Concentrates	Green feed	Hay	g feed units
kg	g	g	g		g	g	g	
1·0	30	100	50	60	30	125	30	64
1·5	40	150	50	74	35	150	30	72
2·0	56	200	50	98	49	200	30	95
2·5	72	250	60	121	63	250	30	117
3·0	80	300	60	134	70	300	30	133
3·5	88	350	60	146	77	350	30	148
4·0	96	400	70	158	84	400	30	164

In this plan the hay is mainly clover and mixed grass and the green feed mostly lucerne, except in early summer when it is clover and mixed grass. The concentrates in winter consist of 75 per cent pelleted feed, 22 per cent equal parts of barley and oats and 3 per cent monosodium phosphate. In summer the mixture consists of 57 per cent pellets, 40 per cent grain and 3 per cent monosodium phosphate. The percentage composition of the pelleted mixture is ground barley 22, ground oats 12, ground wheat 10, wheat bran 10, wheat feed 10, soya bean meal 10, yellow maize meal 8, lucerne meal 5, meat-and-bone meal 4, fishmeal 3, skimmed milk powder 2, minerals 1·5 and charcoal 0·5. Digestible true protein is reckoned as 125 g per feed unit, a little more at the beginning, a little less towards the end of fattening. The two breeds principally represented at the station, White

Table 21

Winter ration for rabbit of average weight 2·5 kg
(Nielsen *et al.*)

Feed	Amount	Water	Crude fibre	Digestible crude protein	Energy of digested feed (EDF)
	g	g	g	g	kcal
Hay taken as half clover half timothy	60	6·8	16·6	3·2	100
Turnips	250	229·5	2·8	2·2	77
Concentrates	72	8·1	5·0	9·9	213
	382	244·4	24·4	15·3	390

Landrace and French Voedder, increase in weight from 1·42 and 1·95 kg at 10 weeks of age to 3·09 and 3·92 kg at 22 weeks of age, average gains of 20 and 23·5 g per day, respectively. We have calculated the nutritive value of these rations for rabbits of 2·5 to 4·0 kg. Details of the analysis of the ration for the rabbit of 2·5 kg are given in Table 21.

The nutritive values of the rations for rabbits of 3·0 to 4·0 kg are summarised below.

Table 22

Nutritive value of daily winter rations for rabbits of 3 to 4 kg (Nielsen *et al.*)

Weight of rabbit kg	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
3·0	291·2	25·4	16·9	430
3·5	338·0	26·5	18·5	468
4·0	385·9	30·4	20·5	525

In each of these rations the amount of digestible crude protein per thousand kcal EDF is 39 g and the nutritive ratio is 1 : 3·4 or 1 : 3·5. Digestible crude protein per kg bodyweight decreases from 6·1 to 5·1 g daily. Crude fibre in dry matter is 17 or 18 per cent.

The National Research Council, Committee on Animal Nutrition, U.S.A. (1954) gives examples of rations to meet the needs of normal growth and fattening of rabbits of 4 lb (1·8 kg) to 7 lb (3·2 kg) gaining on average 1·2 oz (34 g) per day. The rations provide 0·17 lb TDN and 0·05 lb (22·7 g) digestible protein for the rabbit at a weight of 4 lb and 0·25 lb TDN and 0·08 lb (36·4 g) digestible protein at a weight of 7 lb. Our estimates of the nutritive value of these rations are given below (Table 23). There is evidence, however, that such a ration provides protein greatly in excess of the rabbit's needs. Average gains by New Zealand White rabbits equal to or greater than the gain postulated in the N.R.C. report have been obtained with diets containing proportionately more hay and less high-protein concentrates. One such diet consisted of, per cent, alfalfa hay 50, maize 21, oats 15, soya bean oil meal 3, molasses 10 and dicalcium phosphate 1. This diet contained 13 per cent crude protein on an air-dry basis. Another consisted of, per cent, mixed hay (70 per cent alfalfa, 30 per cent timothy) 41, maize 20, barley 20, soya bean oil meal 8, citrus pulp 8, molasses 1, chromium oxide 1 and dicalcium phosphate 1. This diet contained 14 per cent crude protein and in a digestibility trial provided 9·4 per cent digestible crude protein (Smith *et al.*, 1960). In those studies rabbits of about 3 lb were allowed to eat as much food as they wanted and they had access to water and iodised salt.

In the Swedish feeding programme described by Hagelin (1935) rabbits intended for slaughter are given at 5 months of age a fattening diet in place of the one to which they were weaned. This diet, which is considered very satisfactory, consists of oats and water in the morning and a mash of oatmeal with milk, boiled potatoes with skins and hay in the

Table 23

Ration for normal growth and fattening from 4 lb (1·8 kg) to 7 lb (3·2 kg)
(National Research Council, U.S.A.)

Feed	Per cent	Amount lb	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
At 4 lb							
Alfalfa hay		0·07	32	3·6	9·9	4·1	60
Pellets:		0·25					
Soya bean oil meal	18		20	1·9	1·0	8·2	80
Linseed oil meal	4		5	0·5	0·4	1·6	17
Alfalfa meal	40		45	2·9	9·2	7·4	122
Wheat bran	15		17	1·8	1·8	2·4	45
Barley, ground	18		20	2·9	1·3	1·8	64
Oats, ground	4		5	0·6	0·5	0·4	15
Salt	1		1				
			145	14·2	24·1	25·9	403
At 7 lb							
Alfalfa hay		0·08	36	4·1	11·1	4·6	68
Pellets as above		0·39	177	16·6	22·2	34·1	537
			213	20·7	33·3	38·7	605

Digestible crude protein per thousand kcal EDF 64 g
Digestible crude protein per kg bodyweight 14·4 g at 4 lb, 12·1 g at 7 lb
Nutritive ratio 1 : 1·8
Crude fibre as percentage of dry matter 18 and 17

evening. The amounts given provide, according to Hagelin, 0·107 feed unit and 10·32 g digestible protein per head per day.

Table 24

Fattening ration with milk
(Hagelin)

Feed	Amount g	Water g	Crude fibre g	Digestible crude protein g	Energy of digested feed (EDF) kcal
Hay (as medium quality meadow hay)	85	12·3	21·2	4·7	134
Oats	30	7·3	6·4	5·2	175
Oatmeal	30				
Potatoes (raw weight)	60	45·0	0·5	1·0	57
Milk, skimmed	50	45·2	—	2·0	21
	255	109·8	28·1	12·9	387

Digestible crude protein per thousand kcal EDF 33 g
Nutritive ratio 1 : 4·3
Percentage crude fibre in dry matter 19

A Japanese report (Ando, Kojima, Hetsuka and Sera, 1956) of the effect of castration on fattening male rabbits of the Japanese white breed says that the ordinary growth ration, not described, was given until the fattening experiment began, when the ration was a mixed ration supplemented by raw sweet potatoes and raw sweet potato vines. The mixed ration consisted of, per cent, rice bran 30, wheat bran 20, corn 40, soya bean cake 5, fishmeal 5 and to this was added 1 per cent of a mineral mixture. The control group in the 42-day fattening experiment ate 84·1 g mixed ration, 85·9 g sweet potatoes and 102·0 g sweet potato vines. The average initial weight was 2·5 kg and the final weight at slaughter at 246 days of age was 3·3 kg. The average daily gain was therefore 17·6 g. We have not sufficient information to calculate the digestible protein and energy value of the diet but the crude protein content is given as 14·25 g and the nutritive ratio as 1 : 6·5. The percentage crude fibre in the dry matter of this ration is only 7·4, the lowest of all the rations we have studied.

Antibiotics

There is a large body of experimental evidence that weight gain in young pigs, poultry and cattle may be stimulated by the inclusion of a small amount of antibiotic in the ration. The mode of action of antibiotics on growth is not properly understood. Control of infection may explain the beneficial effect on weight gain in some circumstances but in others this is probably not the whole story. In a review on antibiotics in nutrition Braude, Kon and Porter (1953) cited their own unpublished observations and those of Lawrence and McGinnis (1952) that growth of rabbits was not affected by the addition to the diet of the antibiotic terramycin. Since then lack of effect of antibiotics on growth of rabbits has been confirmed with Aurofac, a mixture of aureomycin and vitamin B_{12} (Huang *et al.*, 1954; Nielsen *et al.*, 1958) as well as with aureomycin alone or terramycin (Huang *et al.*, 1954). On the other hand, Russian workers reported improved weight gain in groups of rabbits given aureomycin as a supplement to winter rations. Penicillin, or a mixture of aureomycin, penicillin and synthomycin were less effective (Kurilov, Gorškov and Mašurko, 1958; Kurilov, Lipatova and Mašurko, 1958). Both the Russian and the Danish workers reduced mortality in young rabbits by giving antibiotic. Even more dramatic was the reduction by 75 per cent in mortality from mucoid enteritis reported by Templeton (1953) to result from administration of 10 or 20 mg of aureomycin per ton of feed although subsequent attempts to lower enteritis mortalities with aureomycin were unsuccessful. Lawrence and McGinnis (1952) were careful to point out that the rabbits in their experiments were not exposed to disease and none showed signs of disease. The results of those and other American studies cited by Casady and Gildow (1959) support the view that administration of antibiotics has no significant effect on weight gain and is not associated with improved feed conversion except in experiments in which high mortality is reduced by the antibiotic. In the Russian studies the amount of aureomycin given was 0·5 or 1·0 mg per kg bodyweight daily. In the Danish trial 10 or 20 mg Aurofac per feed unit of ration were given. Much larger amounts of

Table 25

Summary of calculated nutritive value of some recommended rations

Average weight kg	EDF kcal	Digestible crude protein			Energy from digestible protein (Dig. cr. prot. × 5·65) kcal	Nutritive ratio	Cr fil i d ma
		g/day	g/kg/day	g/1000 kcal			
				Maintenance			
2·5	304 to 394	11·7 to 15·1	4·7 to 6·0	38	66 to 85	1 : 3·6	1
3·0	319	9·0	3·0	28	51	1 : 5·3	2
3·0	386	14·1	4·7	37	80	1 : 3·8	2
3·5	331	10·1	2·9	30	57	1 : 4·8	2
4·5	429	19·6	4·4	46	111	1 : 2·9	2
				Normal growth			
1·25	335	18·7	15·0	56	106	1 : 2·2	1
3·0	477	27·6	9·2	58	156	1 : 2·1	2
				Normal growth and fattening			
2·5	390	15·3	6·1	39	86	1 : 3·5	1
3·0	430	16·9	5·6	39	95	1 : 3·4	1
3·5	468	18·5	5·3	39	105	1 : 3·5	1
4·0	525	20·5	5·1	39	116	1 : 3·5	1
1·8	403	25·9	14·4	64	146	1 : 1·8	1
3·2	605	38·7	12·1	64	219	1 : 1·8	1
				Fattening			
	387	12·9	—	33	73	1 : 4·3	1
				Pregnancy			
4·5	437	25·1	5·6	57	142	1 : 2·1	2
				Lactation			
Medium sized breed	1412	49·9	—	35	282	1 : 4·0	2
	1246	48·7	—	39	275	1 : 3·5	1
	1180	46·3	—	39	262	1 : 3·5	1
Medium sized doe in first month with 6 young	676	24·7	—	37	140	1 : 3·8	1
	1228	75·5	—	61	427	1 : 1·9	1
4·5 (litter of 7)	1703	107·4	23·9	63	607	1 : 1·8	1
				SG1 Pelleted Diet			
				63		1 : 1·8	1

aureomycin, 5 to 50 mg per kg bodyweight daily, are reported to be toxic (Ambrosioni and Masoni, 1955; Kivman, Cumačenko, Smol'nikova, Mitrofanov and Ruhadze, 1959). According to a Japanese worker (Tsuneishi, 1959) administration of antibiotics reduced the amount of riboflavin in the digestive tract of the rabbit. The fall was less when riboflavin was given with the antibiotics.

Yield and quality of products

Meat

Domestic rabbits, whether raised primarily for meat or for fur, yield a readily marketable carcase. In Britain many of the carcases used to come from animals reared primarily for fur. A study of liveweights at slaughter and carcase weights of over a thousand rabbits of different breeds and crosses killed for fur and meat in Britain showed that average liveweights of the males ranged from 3·3 lb in the Dutch rabbit to 7 lb in the Flemish Giant and of the females from 4·3 lb in the Tan to 8·8 lb in the Flemish Giant. The average weight of the dressed carcase as percentage of the liveweight at slaughter ranged from 54 to 69 with the exception of the Himalayan Rex female of which there was only one. The age at slaughter varied, since the time of killing depended on the condition of the coat (Dudley and Wilson, 1943). In America rabbits reared primarily for meat are killed at a liveweight which gives a popular weight of carcase irrespective of the condition of the pelt. The large New Zealand White rabbit is ready for market when weaned at 2 months and, with a liveweight of 4 to 4¾ lb, yields a carcase of 50 to 59 per cent of the liveweight, 78 to 80 per cent of which is edible. In areas where the demand is for slightly heavier carcases the carcase is usually about 55 to 65 per cent of the liveweight with 87 to 90 per cent of it edible (Templeton, 1952; Templeton and Kellogg, 1959). It should be noted that the American and British figures for carcase as percentage of liveweight are not strictly comparable since although the dressed carcase in both countries contains the liver and heart the head is retained on the British carcase and not on the American. In a carcase weighing 2 kg the head accounts for 10 per cent of the weight (Nielsen *et al.*, 1958).

Estimates are available of the amount of feed required to produce a pound of marketable liveweight of New Zealand White rabbit which take account of the feed eaten by the doe during pregnancy, and that eaten by the doe and her litter from parturition to slaughter of the young. With a ration of alfalfa hay and pellets 4 lb feed were required to produce a pound liveweight of rabbit at 56 days. It was impossible to correct for feed eaten by young rabbits which were lost but in 40 litters which suffered no mortality after 21 days only 3·35 lb feed were required. The amount required increases progressively with increasing age at slaughter. For instance in the above experiment when rabbits were reared to 64 days of age instead of 56 days the additional average increase in liveweight of 0·7 lb increased the amount of feed required from 4 to 4·58 lb per pound liveweight. The increased money value of a litter at 64 compared with that at 56 days of age did not justify the additional labour (Templeton, 1952).

It is of interest to compare the amount of feed required to produce a pound of liveweight of New Zealand White rabbit at 56 days of age with that required in King Wilson's experiment with Brown rabbits reared to 12 weeks of age. We have done this on a dry matter basis because of the different types of rations used. Assuming 90 per cent dry matter in the American alfalfa hay and pellet ration, and no mortality in young after 21 days, 3 lb DM are needed from mating of doe to slaughter of young per pound liveweight of young. In King Wilson's experiment only the feed from the beginning of lactation is recorded but even this amounts to 5·8 lb DM per pound liveweight of young of this smaller type to the later age.

Templeton (1952) also estimated the annual production of 64-day-old rabbits by does remated 42 days instead of the usual 56 days after parturition. The results are shown in Table 26.

Table 26

(Templeton, 1952)

		Breeding schedule	
		56 days	42 days
Does maintained	No.	16	16
Matings made	No.	191	197
Conceptions	No.	123	110
Conceptions	Per cent	64·4	55·8
Possible litters per doe per year	No.	4·20	5·00
Litters produced per doe per year	No.	3·55	3·79
Average amount of rabbit produced per doe per year	lb	95·4	97·7

With the prevailing prices of and returns for young rabbits the difference in returns per doe per year above feed cost was not sufficient to offset the additional labour.

The amount of feed required per 100 lb liveweight gain from weaning to a liveweight of 6 lb was investigated by Kellogg *et al.* (1949). Approximately 722 lb feed, of which 38 lb were succulent, were required to put 100 lb of gain on 504 rabbits from weaning to arrival at 6 lb liveweight. Neglecting the small amount of green feed, and assuming a dry matter content of 90 per cent in the remaining 684 lb feed, it may be calculated that 6 lb DM were required per lb gain. Mortality during the experiment was 17 per cent and feed eaten by rabbits which died was charged to the gains made by those which survived.

The same workers castrated a group of 95 bucks at weaning and compared the time they took to reach 6 lb weight and the amount of total digestible nutrients they required per 100 lb gain with the time and requirement of their doe littermates. From their findings and observations on time taken to reach 6 lb by uncastrated bucks and their doe littermates in another experiment they concluded that it is logical to believe that castration does not increase the utilisation of the feed when the rabbits are to attain a weight no greater than 6 lb.

A more direct investigation of the effect of castration on the fattening of older rabbits was made by a group of Japanese workers (Ando *et al.*,

1956). They had four groups of fifteen male rabbits of the Japanese white breed. Three groups were castrated at 9, 17 and 29 weeks of age and a control group was not castrated. Ages at slaughter were about 8 months. All groups were fed alike. Castration was found to have scarcely any effect on bodyweight gain but it increased storage of fat. Dressed weight was 48 or 49 per cent in the castrated groups and 50 per cent in the uncastrated group. A group of Russian workers (Popov, Kurilov and Novikov, 1957) reported the results of giving diethylstilboestrol, 90 μg per animal daily for 60 days from 3 months of age, to a group of eight male and seven female rabbits. Compared with a control group given no hormone, total gain was improved by 31·7 per cent in bucks but was reduced by 17·7 per cent in does.

Templeton's observations that dressed carcase yield and the proportion of edible meat in the dressed carcase are greater in rabbits reared to 64 days than in those killed at 56 days are in line with the earlier observations of Hammond (1931) who showed that both increased with age. Hammond pointed out that the better the animal was fed the higher the proportion of edible meat. A study of fryer rabbits by Hankins, Hiner, Templeton and Kellogg (1960) shows that high grade carcases yield a greater proportion of edible meat than do lower grade carcases. In the early stages of growth there is no difference between males and females but later the female gives the higher proportion of edible carcase, chiefly because of a higher fat content. The higher fat content of meat from does than from bucks is seen in the results of analyses of the flesh of White Angoras (Wilson and Morris, 1932) (Table 27) and of Havanas (Wilson and Botham, 1933–34). The table shows the effect of age on fat content. Also included in Table 27 are the results of analyses of rabbits made in the United States about the same time (McMillin, 1931). We have not found any recent publication giving the composition of the young rabbits now popular on the American market. Tables of food composition such as those of Watt and Merrill (1950) do not include rabbit. According to Chatfield and Adams (1940) the flesh of domestic rabbit, of dressed weight 56 per cent, age not stated, contains 20·8 per cent protein and 10·2 per cent fat. All of the values for protein content of rabbit flesh are similar to values for the flesh of broiler, fryer and roaster chicken, 21 per cent, given by Chatfield and Adams. The fat content of rabbit flesh varies considerably according to age, sex and breed and, as Hutchinson (1947) has shown, is profoundly influenced by the type of diet. The New Zealand rabbit meat analysed by McMillin contained 12 per cent fat at 13 weeks of age. Recent analyses of the fat content of the edible meat of New Zealand White rabbits killed at 8 weeks gives fat contents of 10·21, 8·09 and 6·32 per cent, respectively, for prime, choice and commercial grades of carcases (Hankins *et al.*, 1960). These compare favourably with the values of 4·4 to 4·8 per cent fat in chicken flesh, reported by Chatfield and Adams.

The weights of dressed carcase given by McMillin did not include weight of heart, liver and kidneys. Wilson and Morris included those organs in dressed carcase and in the samples of edible meat for analysis. In Italy Geri (1958) gave the composition of the flesh of rabbits of different breeds and crosses, mainly Flemish Giant, native breeds and crosses of these,

Table 27

Composition of rabbit meat

Breed	Age	Sex	Live-weight lb/oz	Dressed weight lb/oz	Dressing percent-age	Composition per cent				Sources
						Water	Protein	Fat	Ash	
White Angora	11 m	F	4/9¼	2/12½	61	67·3	20·3	5·8	1·4	*
,, ,,	11 m	M	4/8¾	2/10½	58	69·7	21·1	1·7	1·5	
,, ,,	adult	F	4/10⅛	3/1¾	67	63·0	20·0	9·1	1·3	
,, ,,	adult	M	4/9⅜	2/14	63	66·9	21·9	3·3	1·3	
American White	1½ y	F	7/6½	3/12¾	51	67·0	21·0	11·3	1·1	
,, ,,	10 m	F	7/12¾	3/15¾	51	63·1	20·4	15·7	1·0	†
Chinchilla	10 w	M	4/3½	2/2⅛	51	70·4	20·5	8·5	1·1	
New Zealand	13 w	M	5/6½	2/11¾	51	67·2	19·7	12·1	1·1	

* Wilson and Morris, 1932
† McMillin, 1931

killed at 120, 150 and 180 days. Protein content ranged from 19·22 to 24·62 and fat content ranged from 2·54 to 8·48 per cent.

The fat of the rabbit is usually white but some rabbits have an inborn tendency to produce yellow fat. The incidence is higher in albino than in other rabbits (Wilson and Dudley, 1946). The yellow colour of the fat has been identified as xanthophyll pigments (Willimott, 1928) and is deepest in rabbits which have become fat and then lost condition (Hirzel, 1935). The pigment comes from green feed and does not appear in the fat if such feeds are omitted from fattening rations.

Wool and fur

The Angora rabbit is the only breed from which wool for spinning can be obtained. In Britain young Angoras are clipped at 8 weeks and thereafter at intervals of 13 weeks. The annual yield may be 5 to 9 oz (142 to 256 g) and should be in the region of 7 to 9 oz (199 to 256 g) (Wilson, 1959). Much higher average yields from Angoras are reported on the Continent and in the United States where heavier types of Angora are kept. Several years ago Niehaus (1953) reported that the average yield of wool of rabbits in a good herd had risen in 10 years from 350 to 560 g with peak yields of 750 to 800 g and more but went on to say that the broad mass of rabbit keepers do not exceed the average of about 350 g. In Denmark highest yields ever reached at the Favrholm Station were 476 g from females and 491 g from males in 1956–57 (Nielsen *et al.*, 1958). According to Templeton and Kellogg (1959) Angoras in the United States are sheared or plucked every 10 to 11 weeks and an animal in a good commercial herd should produce, on average, about 14 oz (400 g) of wool a year.

Little exact information is available about the effect of diet on wool production. Importance is generally attached to protein quantity and quality, in particular the sulphur-amino acid content. Richter and Hundt (1934) obtained increased wool yield by addition of a protein supplement to a winter ration of hay and beet and according to Niehaus (1953), research in Germany showed that improved feeding could increase wool yields by from 50 to 100 per cent. Early records of the Harper Adams College show that yield of wool was much greater from rabbits on a normal mixed diet of mash, oats, hay and greens or roots than from rabbits given little or no concentrates. Fangauf and Dreyer (1940) obtained no appreciable improvement in wool production from the inclusion of bean meal and soya bean meal in the concentrated ration of dried potato flakes and sugar beet slices. Bortoli (1954) used bovine horn as source of supplementary cystine in the diet for Angora rabbits but there was no significant increase in wool yield. According to Pickard (1928, 1928–29*a*,*b*, 1931) a few drops daily of cod liver oil increased yield of wool by 10 to 16 per cent.

Most of the rabbit skins produced in the United States are from young animals slaughtered primarily for meat and usually while they are shedding the baby coat of hair and developing a new coat. The skins are small and the fur is of poorer quality than that of older rabbits. The proportion of first grade pelts in fryer rabbits killed at 56 to 76 days of age may be raised by restricting the amount of grain in the ration. This is apparently because growth is slower than in self-fed rabbits and the animals are

killed before they have begun to shed their hair (Kellogg and Templeton, 1948).

Reference has been made to the effect of diethylstilboestrol on rate of gain of bucks. Improvement in quality of skins as a result of biological castration with this hormone was reported at the same time (Popov *et al.*, 1957).

Purified diets

Attempts to obtain a diet adequate for growth and reproduction from a combination of purified ingredients containing only identifiable nutrients have not been entirely successful. In every instance some improvement has been obtained as a result of inclusion of some food, or extract of food, the importance of which has not been established in terms of a specific nutrient or nutrients. For instance the "simplified" diets of Hogan and Hamilton (1942), which successfully supported growth and reproduction, contained yeast or yeast extract or liver extracts. Hove and Herndon (1957*b*) found that the improvement in growth of rabbits on a diet of purified casein, sucrose, cellulose, lard, minerals and vitamins which resulted from increasing the casein percentage or supplementing the casein with amino acids did not equal in degree or consistency the improvement which resulted from the addition of soya bean meal. Growth similar to that obtained with a stock diet has been obtained in young rabbits given a purified diet containing 25 or 30 per cent casein (Wooley, 1954; Wooley and Mickelson, 1954) but the experimental period was short, only 4 weeks.

Purified diets, despite the fact that they do not support as good growth as stock diets, have of necessity been used in attempts to estimate the requirements of the rabbit for specific nutrients. The conclusions, which are discussed in the chapters on requirements, may need modification when a satisfactory basal diet becomes available.

Requirements of energy

Basal or standard

The basal or standard energy requirements of rabbits of different weights have been measured (Benedict, 1938; Lee, 1939*a*,*b*, 1942). In mammals the energy requirement per unit bodyweight varies inversely with the body size and, hence, since the rabbit is one of the smallest farm mammals, its energy requirement is relatively high. The basal requirements for 24 hours of rabbits of different weights, calculated from the equation of Lee (1939*b*) in round figures are shown in Table 28. The requirement of the rabbit is roughly 3 times that of cattle per unit of bodyweight. There does not appear to be any difference between different breeds such as Angora, Blue Vienna and Chinchilla (Tomme and Loria, 1936).

Maintenance

Basal energy requirement is determined when the animal is, as nearly as possible, in a condition of complete rest, neither moving nor even

digesting or absorbing food. Estimation of maintenance requirement must take account of the energy expenditure on eating, drinking, digesting and the other ordinary activities of living.* Swedish workers under the guidance of Axelsson studied the effect of diet on energy metabolism in the rabbit (Hellberg, 1949; Eriksson, 1946, 1952; Axelsson and Eriksson, 1953) and Axelsson (1949) formulated requirements for maintenance in terms of metabolisable energy. According to Brody (1935) for mammals in general the energy value of the total digestible nutrients for maintenance should be of the order of twice the basal expenditure. The National Research Council, Committee on Animal Nutrition, U.S.A. (1954) report on nutrient requirements for rabbits gives energy requirements in terms of total digestible nutrients but it is pointed out that the recommendations represent observed intakes with minor adjustments to present a picture consistent with theory.

It is of interest to compare estimated requirements of energy for maintenance derived by doubling the basal requirement and Axelsson's estimate of maintenance requirement with the energy of digested feed (EDF) of recommended diets (Table 28). The energy of digested feed is the heat of combustion of the feed, less the heat of combustion of the undigested materials in the faeces. Axelsson's metabolisable energy represents gross energy less energy lost as methane and in urine as well as energy lost in faeces. For a comparison with the energy of digested feed a correction must be made to Axelsson's estimates for energy in urine. Energy value of methane in the rabbit is small and is usually neglected. The relation between EDF and metabolisable energy varies with level of gross energy intake. It may be calculated from the energy balance data of Hellberg (1949) that EDF as a percentage of metabolisable ranges from 106 at Axelsson's higher level of allowance to 109 at the lowest. The EDF values obtained by application of this correction to Axelsson's estimates of requirements are given in Table 28.

The table shows good agreement between Axelsson's estimates of metabolisable energy required for maintenance and theoretical estimates obtained by doubling basal requirement for liveweights of 2·5 to 4·0 kg. The EDF of recommended maintenance rations is rather more than estimated requirement for maintenance except for Schürch's ration.

Other Scandinavian standards summarised by Axelsson (1949) are in feed units (F.U.). Larsson in Sweden allowed 0·08 to 0·10 F.U. for a rabbit of 3·0 kg. Olsen in Denmark allowed 0·051 F.U. for a weight of 1·5 kg rising to 0·088 F.U. for 4 kg. Høie in Norway allowed 0·08 to 0·105 F.U. for a rabbit of 3·5 kg. According to Axelsson the metabolisable energy value of the Scandinavian feed unit (1 kg barley) for the rabbit is 3025 kcal. Olsen's allowances for maintenance and the lower limits of the standards of Larsson and of Høie are below Axelsson's standards. According to Romanovskii (1954) the maintenance requirement of an adult

* French workers have made some interesting and important observations on the metabolic reactions after the taking of food in the rabbit (Cahn and Houget, 1952*a*,*b*; 1953, 1960) and the utilisation of energy in feed in relation to plane of nutrition has been studied recently in Germany (Nehring, Hoffmann and Schiemann, 1959).

Table 28

Daily energy requirements for maintenance

Bodyweight kg	Basal (Lee, 1939*b*) kcal	Maintenance as twice basal kcal	Maintenance metabolisable energy (Axelsson, 1949) kcal	Axelsson's estimates converted to EDF kcal	EDF of recommended maintenance rations kcal	
1·5	80	160	190			
2·0	100	200	230	251		
2·5	120	240	260	278	304	Harper Adams
					394	College
3·0	140	280	290	310	319	Hagelin
					386	
3·5	160	320	320	339	331	Schürch
4·0	180	360	350	371		
4·5	200	400	380	403	429	N.R.C.

rabbit weighing 4 kg is 135 g feed units. This feed unit is the feeding value of 1 g oats. A rough conversion to Scandinavian feed units on the basis of the digestible energy for rabbits of oats and barley suggests that this standard is not much different from Axelsson's standard.

Reproduction

For breeding bucks Axelsson recommended 5 to 10 per cent above maintenance allowance and says Høie allowed 30 to 40 per cent above maintenance. The National Research Council, U.S.A. report gives the same maintenance requirement for bucks as for does and there is no mention of an additional allowance for breeding bucks.

Gestation in the rabbit usually lasts about 31 days, the number of days depending on the size of the breed and the number of young (Rosahn, Greene and Hu, 1935; Wilson and Dudley, 1952). There is very little growth of the foetus in the first 20 days, most of it taking place in the last 10 (Hammond, 1936). Birthweight of young is affected by the diet of the doe during the period of rapid foetal growth (Hammond, 1936; Bertelli, 1936). Sandford (1957) recommends one and one-third times maintenance at the start of pregnancy rising to twice maintenance at the end. The extent to which the doe's ration should be increased in pregnancy will depend on the extent to which her ordinary ration exceeds bare maintenance requirement. The National Research Council, U.S.A. energy allowances for pregnant does, based like other N.R.C. allowances on observed intakes of rabbits doing well, are the same as the maintenance allowances. Axelsson (1949) and Larsson recommended an increase of 5 per cent over maintenance requirement and according to our calculation this brings Axelsson's allowance in pregnancy to about the same level as the N.R.C. allowance for either maintenance or pregnancy. Axelsson (1949) pointed out that the Danish standards of Olsen recommended a 30 to 35 per cent increase and the Norwegian standards of Høie a 30 to 40 per cent increase over maintenance and suggested that the higher condition which the Swedish maintenance standards postulate at the start of pregnancy might account for the difference. Certainly the difference

between the Danish standard and the lower limit of the Norwegian standard on the one hand and Axelsson's standard and the upper limit of Larsson's standard for maintenance on the other hand could explain the different increases proposed for pregnancy. For example, if the Danish maintenance allowance for a weight of 4 kg is converted to terms of metabolisable energy and increased by 35 per cent the value obtained is approximately the same as that obtained by increasing Axelsson's maintenance allowance by 5 per cent.

It is generally agreed that in rabbits as in other livestock overfatness in breeding females has an adverse effect on reproduction and should be avoided.

Lactation

An extensive study (Bertelli, 1936) of milk production on breeding farms has shown that yield depends on diet. During the first 5 days, yield varied from 25 g, which was usually insufficient to keep the young alive, to 180 g which gave excellent growth. On the average, the daily yield, during the height of lactation from the 12th to the 25th day, was about 35 g per kg liveweight. The maximum weight of the rabbits studied was 4 kg. Yield began to decline about the 30th day. The period of effective lactation did not exceed 45 days. Bertelli reckoned that the total yield for a lactation should be not less than 2·4 litres and may be much more. According to calculations by Wendt, v. (1931–32) a Silver Fox doe rabbit, weighing less than 6 lb, which reared a litter of ten, must have produced at least 100 g milk daily, i.e., 5·6 litres for an 8 weeks' lactation. That is roughly equivalent to a yield of 10 gallons daily for a cow.

A study of milk intake of litters of Chinchilla Giganta rabbits showed that intake rose to a peak during the third week and tailed off to the sixth week. Effective lactation ceased at about 50 days. Peak consumption per litter per week was 739, 1450 and 1245 g, respectively, for litters of two, five and eight young (Davis, 1957). The mean of these three values calculated per kg per day, assuming an average liveweight of 4·5 kg, agrees closely with Bertelli's average peak production. If it be assumed that the efficiency with which a doe converts the EDF of her total ration into milk energy is the same as the efficiency of a cow yielding 10 gallons a day, i.e., about 45 per cent according to Leitch and Godden (1941), it may be calculated that a doe will require a ration supplying $\frac{100}{45}$ times the energy value of her milk. It will be seen from the table below (Table 29) that the energy value of rabbit's milk may be from about 200 to 300 kcal per 100 g. A yield of 1450 g per week or 207 g per day at the height of lactation would have an energy value of 414 to 621 kcal. The amount of EDF in the total ration should therefore be 920 to 1380 kcal. These amounts are 214 to 322 per cent of the EDF of the N.R.C. maintenance ration for a doe weighing 4·5 kg and roughly 228 to 342 per cent of Axelsson's maintenance requirement, extrapolated to a weight of 4·5 kg and converted to EDF (Table 28). It is of interest to compare these estimates with recommended allowances for lactating does.

According to Axelsson (1949) the energy allowances as percentage of maintenance allowance by weight in weeks 1–2, 3–4, 5–6 and 7–8 of

Table 29

Percentage composition of rabbit's milk

Water	Protein	Fat	Sugar	Ash	Reference	Calculated energy value kcal/100 g	Energy from protein kcal
69·50	15·54	10·45	1·95	2·50	König (1919)	192	88
	11·4–15·0	12·1	1·8	2·50	Butterfield (1929)	181 to 204	62 to 85
	10·5	16·7	2·0	2·5	Wendt, v. (1931–32)	222	59
69·50	12·00	13·50	2·00	2·50	Morris (1936)	201	68
54·3	18·5	22·8	1·4	3·00	Neumister and Krause (1956)	321	105
59·0	13·6	22·7	2·3	2·4	Neumister and Krause (1956)	296	77
65·9	11·5	17·0	2·0	3·6	Neumister and Krause (1956)	230	65
					Cow's milk		
87·3	3·4	3·7	4·9	0·7	Morris (1936)	73	19
					Goat's milk		
86·9	3·8	4·1	4·6	0·8	Morris (1936)	77	21

lactation are 200, 330, 370 and 400. Corresponding percentages given by Larsson are 350 for weeks 3–4 and 600 for weeks 7–8 and by Høie 265 for weeks 3–4. All of the recommendations for allowances in the third or fourth week of lactation are in good agreement with the estimate based on peak milk yield. Schürch (1949) gives an allowance for a doe of medium size breed with a litter of five young. We cannot compare the allowance with his maintenance allowance because of uncertainty as to the weight of the doe, but the amount allowed in the second month is 0·140 to 0·22 starch unit compared with 0·11 to 0·14 in the first month of lactation. A Russian paper puts the lactation allowance of a 4-kg doe at up to 345 g feed units or 256 per cent of the maintenance allowance of 135 g feed units (Romanovskii, 1954). This is in reasonable agreement with our estimate. The N.R.C. allowance for a doe of 4·5 kg with seven young is roughly 400 per cent of the N.R.C. maintenance allowance. The estimated EDF of Hagelin's Swedish rations for breeding does is 306 to 443 per cent of that in the maintenance rations. Sandford (1957) calculates that an 8-lb doe producing about 4 oz milk with an energy value of 250 kcal, assuming an efficiency of 45 per cent, will require 550 kcal of food energy or about twice the maintenance requirement. He points out, however, that if allowance is made for the feed consumed by the young when they start eating solid feed the total needs of the doe may rise as high as four times maintenance at the end of the fourth week of suckling. Inclusion in the estimated requirement of the doe of the solid feed needs of her litter accounts for the high estimates of requirement in late lactation made by some authorities.

In the study made by Davis (1957) peak consumption per litter when the number of young was five was twice that of a litter of two. The young in in the litter of two obtained more milk per head than did those in the litter of five. This might be due in some measure to greater individual birth-weight in the small litter compared with large litters but undoubtedly individual intake by young in larger litters is limited by the supply of milk.

Evidence that weight gain of sucking young is influenced by the size of the litter has been given by Hammond and Marshall (1925), Jespersen and Olsen (1942) and by Venge (1953). Hammond eliminated any effect of difference in birthweight on subsequent gain by arranging young of about the same weight into litters of one to nine young. With up to three young weight gain to 3 weeks was much more rapid than with four to seven and with as many as nine young growth was seriously retarded. Venge's litters decreased in average birthweight with increasing size of litter. He found a significant effect of litter size on average gain until weaning, amounting to 20 to 30 per cent of the total variance, but after weaning the difference decreased and by 56 days was only 10 per cent of variance. In large litters young began to eat supplementary food earlier than in small litters.

The need to define the size of litter to which a lactation allowance relates was recognised in the N.R.C. report. Schürch (1949) did so too. He gave the recommended allowance for a doe with a litter of five and the extra amount needed for each additional one in the litter.

Growth and fattening

Different breeds of rabbits vary more in adult weight than any other type of domesticated livestock. The entire range appears to be from about 2 to 20 lb. The small Dwarf breed averages about 2 lb and the Flemish Giant 10 lb or more. These differences are not due to feeding although they may be affected by it, but are hereditary. Large breeds, although they make greater daily gains, take longer to reach mature weight than small breeds. This is illustrated by the observations of Haring and Gruhn (1951) that the small Schwarzloh breed of mature weight 2·3 kg reached their limit of growth at 210 days, whereas the Giant Chinchilla of mature weight 4·7 kg had not reached the limit at 322 days. Daily weight gain in the second month was 27·9 g by the Giant Chinchilla and 14·9 g by the

Table 30

Weight gain of Chinchilla rabbits
(Hagelin)

Days from birth	Total weight g	Gain per day g
0–14	60–225	11·8
14–30	225–400	10·9
30–45	400–700	20·0
45–60	700–1050	23·3
60–75	1050–1400	23·3
75–90	1400–1750	23·3
90–105	1750–2000	16·7
105–120	2000–2200	13·3
120–135	2200–2350	10·0
135–150	2350–2500	10·0
150–165	2500–2650	10·0
165–180	2650–2750	6·7
180–195	2750–2825	5·0
195–210	2825–2875	3·3
210–225	2875–2925	3·3
225–240	2925–2950	1·7
240–450	2950–3000	0·2

Schwarzloh. In subsequent months gains were progressively less. Danish data for White Landrace and French Voedder rabbits which weighed 3 and 4 kg, respectively, at 22 weeks of age show that they made greatest daily gains, 27 and 31 g, respectively, between the twelfth and the fourteenth and sixteenth weeks (Nielsen *et al.*, 1958). The above table of weight gains of Chinchilla rabbits, well fed in litters of six, shows a plateau of maximum gain of 23 g from 45 to 90 days (Hagelin, 1935).

Recent figures for liveweights and weight gains of New Zealand White rabbits weaned at 8 weeks in the stock colony of the United States Rabbit Experiment Station, Fontana (Casady, 1961) are shown in Table 31.

Table 31

Weight gain of New Zealand White rabbits
(Casady)

Age	Average liveweight		Average daily gain	
	lb	g	oz	g
Birth to 3 weeks	0·1 to 0·8	45·4 to 363·2	0·53	15·1
3 weeks to 8 weeks	0·8 to 4·0	363·2 to 1816·0	1·46	41·5
8 weeks to 14 weeks	4·0 to 7·2	1816·0 to 3268·8	1·17	33·2
14 weeks to 5 months	7·2 to 9·0	3268·8 to 4086·0	0·58	16·5

Unpublished observations on the weights of five litters of four or five Chinchilla Giganta rabbits reared on the pelleted Diet SG1 show gains per day of 15 to 21 g in the first 3 weeks, 32 to 38 g from 3 to 8 weeks, 19 to 24 g from 8 to 14 weeks and 10 to 12 g from 14 weeks to 5 months of age (Clarke, 1961).

The elaboration of energy requirements for growth and fattening requires knowledge of the ratio which the energy of the food used for weight increase bears to the energy of the product. The composition of the gains varies with age within a breed. Other things being equal, the older the animal the higher the proportion of fat to protein in the gain and hence the older the animal the greater the energy required per unit weight gain within a breed. Since animals of large breeds take longer to reach mature weight than those of small breeds their development in terms of fat lags behind that of small breeds. For instance, Fangauf and Immenkamp (1938) found that the most economical gains were achieved in small breeds up to 5 months of age, in medium breeds up to 6 months and in large breeds up to 7 months. Similar observations were made by Hofmann and Steiner (1959). Feed conversion efficiencies showed that it was uneconomic to feed Schwarzloh, Chinchilla and Marburger Feh to more than 4 months of age, Vienna White to 5, Chinchilla Giganta to 6 or Deutsche Riesen to 7 months. In Egypt it has been shown to be uneconomic to continue feeding the small native Baladi breed for meat after 11 weeks of age (Ghoneim, Abou-Raya and El-Abbady, 1958). Differences are found also in the composition of the adults. The fat content of mature carcases is higher in small than in large breeds (Haring and Gruhn, 1951; Hofmann and Steiner, 1959). The fat content of the gain may be affected also by the quantity and quality of feed (Hutchinson, 1947).

According to Schürch, 1 kg pure digestible starch or 1·00 starch unit has a net energy for fat deposition of 2590 kcal. Corresponding values for 1 kg pure digestible fat and 1 kg pure digestible protein are 2·24 and 0·85 starch units, respectively. Schürch used digestibility coefficients from the literature to calculate the percentage of digestible nutrients in the feed of growing rabbits and applied the above starch unit values to obtain the crude starch equivalence (SE) of the feed. The deduction to be made for energy used for mastication of fibre was not known for the rabbit so Schürch used Kellner's value for cattle to calculate net starch equivalence. Composition of weight gains at different liveweights was worked out from published data for growing rabbits of a medium sized breed. Net energy of gain in terms of fat was calculated as the sum of g protein $\times$ 5·7 kcal $\times$ 0·586 and g fat $\times$ 9·4 kcal. Schürch concluded that the total requirement of the growing rabbit was expressed by the equation

$$SE = G \times 0{\cdot}0225 + Z \times 0{\cdot}00045 + 10\% \text{ safety margin,}$$

where G = weight in kg and Z = weight gain in g.

It is of interest to solve this equation for a rabbit of 6 lb (2·7 kg) gaining on average 1·2 oz (34 g) daily for which, according to the National Research Council, U.S.A. report on nutrient requirements of rabbits, the recommended allowance is 0·23 lb total digestible nutrients (TDN) daily. According to Schürch's equation such a rabbit requires 0·084 kg or 0·184 lb starch equivalent. If we take Schürch's value of 2590 kcal as the net energy for fattening of 1 kg pure digestible starch in the rabbit and 2049 kcal as the net energy for fattening of 1 kg TDN, based on data for cattle reviewed by Blaxter (1950), 0·184 lb SE is equivalent to 0·23 lb TDN. This is the amount recommended in the N.R.C. publication.

Axelsson (1949) gives standards for energy requirements in terms of metabolisable energy for weight gain of growing rabbits at different ages. We have made a rough conversion to EDF and to TDN (Table 32). The EDF values were derived by taking 107½ per cent of the metabolisable energy. TDN values were calculated from Axelsson's statement that 1 feed unit (1 kg barley) has a metabolisable energy of 3025 kcal for the rabbit and from the TDN value of 738 g per kg barley obtained by applying the coefficients of Voris *et al.* (1940) to the composition of barley as given by Hagelin.

Table 32

Metabolisable energy requirements for growth (Axelsson) and approximately equivalent EDF and TDN values

Age in weeks	8	10	12	14	16	18	20	22	24
Metabolisable energy, kcal per g gain	3·9	4·7	5·5	6·3	7·1	7·9	8·7	9·5	10·3
EDF, kcal per g gain	4·2	5·1	5·9	6·8	7·6	8·5	9·4	10·2	11·1
TDN, oz per lb gain	15·2	18·3	21·4	24·6	27·7	30·8	33·9	37·0	40·2

The derived TDN values are similar to those given by Sandford (Table 33).

Table 33

Weight gain and nutrient requirements of growing rabbits of medium sized breeds (Sandford, 1957)

Age in weeks	8	10	12	14	16	18	20	22	24
Approx. weight lb/oz	2/2	2/13	3/9	4/2	4/10	5/0	5/5	5/10	5/14
Weekly gain, oz	5½	6	4½	4	3	2½	2½	2	—
TDN required per lb gain, oz	15¼	18¼	21½	24½	27½	30¼	34	37	40½

Requirements of protein

The protein requirement is sometimes expressed by the nutritive ratio which is a measure of the proportion of energy derived from protein. The nutritive ratio is usually calculated from the equation

$$\text{Nutritive ratio} = \frac{\text{digestible fat} \times 2{\cdot}25 + \text{digestible carbohydrate}}{\text{digestible crude protein}}$$

$$\text{or } \frac{\text{TDN} - \text{digestible crude protein}}{\text{digestible crude protein}}$$

It may be calculated also as the ratio of the energy value of digestible crude protein to the energy value of other digestible nutrients in calories. Protein requirement is sometimes expressed as amounts of digestible crude or true protein per unit of bodyweight, or per feed unit or per thousand kilocalories of metabolisable energy or simply per animal per day. Occasionally requirement is given as a percentage of the total ration.

Maintenance

Brody, on the basis of protein minimum experiments, deduced a generalised maintenance requirement for adults of 10 per cent, i.e., a nutritive ratio of 1 : 9. It may be calculated from the amount of TDN and digestible protein required per kg bodyweight for maintenance of weight and N balance in rabbits (Morimoto and Kameoka, 1952) that a nutritive ratio of 1 : 7·8 is sufficient for maintenance. In the course of his digestion experiments Brüggemann (1937) showed that rabbits fed on meadow hay, with a nutritive ratio of 1 : 6, were in N equilibrium. In practice the nutritive ratio of rations recommended for maintenance are narrower, 1 : 3 to 1 : 5, perhaps because of a desire to provide more than the bare minimum protein for young adults or stock going into production and possibly because most of the commonly available green feeds, leguminous hays and grains have ratios within this range (see appendix). Estimates of digestible crude protein requirement in terms of bodyweight range from 2 g per kg (Voinov, 1933; Morimoto and Kameoka, 1952; Romanovskii, 1954) to 4 g per kg (National Research Council, U.S.A., 1954). In recommended rations the supply of digestible crude protein per kg bodyweight is usually 3 to 6 g (Table 25). Scandinavian estimates, in terms of

digestible true protein per feed unit, quoted by Axelsson (1949), range from 60 to 100 g. Axelsson (1949) recommends 30 to 36 g digestible protein per thousand kcal metabolisable energy. The amount of digestible protein per thousand kcal EDF, according to our calculations is 30 in Schürch's ration, 38 in the Harper Adams College ration, 28 or 37 in Hagelin's Swedish rations and 46 in the N.R.C. ration. Requirement of digestible protein as a percentage of air-dry ration is given as 12 by the National Research Council, U.S.A. (1954).

Pregnancy

The calculated nutritive ratio of the N.R.C. rations for pregnant does is roughly the same as the ratio of the ration for growth, 1 : 2. Recommendations for digestible true protein per feed unit in the Scandinavian countries are 100 to 150 g. Axelsson allows 40 to 44 g digestible protein per thousand kcal metabolisable energy. Our calculation of the digestible protein in the N.R.C. ration for a pregnant doe is 57 g per thousand kcal EDF. The requirement of digestible protein is 14 per cent of the air-dry ration, according to the National Research Council, U.S.A. (1954).

Lactation

Templeton (1939) recommended a ratio of 1 : 2·75 to 1 : 4·5 for lactating does, but the more recent N.R.C. recommended ration for a doe with a litter of seven gives a ratio of 1 : 1·8. This is the ratio in the pelleted Diet SG1. In a diet found satisfactory in trials at Harper Adams College the ratio would appear to be 1 : 1·9. The calculated ratio in Schürch's ration for a doe in the first month of lactation with six young is 1 : 3·8 and in the Swedish rations given by Hagelin is 1 : 3·5. Scandinavian recommendations, quoted by Axelsson (1949), are 100 to 130 g digestible true protein per feed unit. Romanovskii (1954) recommends 35 g digestible protein for a 4 kg doe. Axelsson (1949) recommends 48 to 52 g digestible protein per thousand kcal metabolisable energy. According to our calculations the amount of digestible crude protein per thousand kcal EDF ranges from 35 g in one of the Swedish diets of Hagelin to over 60 in the pelleted Diet SG1, the Harper Adams College diet and in the N.R.C. diet. Requirement of digestible protein as percentage of air-dry ration is 20 according to the report of the National Research Council, U.S.A. (1954).

Growth and fattening

The average nutritive ratio of rabbit's milk from the analyses given in Table 29 is 1 : 2. After weaning rabbits given free choice of feeds ate a diet with a ratio of 1 : 2·66 to 1 : 3·00 (Templeton, 1939). Ratios commonly recommended are of the order of 1 : 3 to 1 : 5 (Grünigen, v., 1933; Templeton, 1939; Kellogg *et al.*, 1949). The calculated ratio of rations found satisfactory for Brown rabbits at the Harper Adams College and of rations recommended by the N.R.C. for the fast-growing New Zealand White rabbit is 1 : 2 and that of rations recommended for different breeds in Denmark (Nielsen *et al.*, 1958) is 1 : 3·5. Scandinavian estimates in terms of digestible true protein per feed unit, quoted by Axelsson (1949), are 90 to 100 g at 2 to 3 months and 70 to 80 g at 6 to 7 months in Norway;

120 g at 2 to 4 months in Sweden. In Denmark a little more than 125 g at the beginning and a little less towards the end of fattening is recommended by Nielsen *et al.* (1958). Axelsson (1949) allows 46 or 48 g digestible protein per thousand kcal metabolisable energy at 2 to 3 months decreasing to 36 to 38 g in the eighth and ninth months. Table 25 shows that the Danish rations supply 39 g, the N.R.C. rations for fast-growing New Zealand White rabbits 58 and 64 g, the pelleted Diet SG1 63 g and the Harper Adams College ration 56 g digestible crude protein per thousand kcal EDF. Rabbit milk (Table 29), assuming that all is digested, provides, on average, 58 g digestible protein per thousand kcal.

According to the report of the National Research Council, U.S.A. (1954), for normal growth and fattening of rabbits between 4 and 7 lb liveweight, the requirement of digestible protein is 16 per cent of the air-dry ration. The expected average daily gain is said to be 1·2 oz per head. Such an allowance of protein would seem to be excessive according to results of feeding trials made at Cornell University (Smith *et al.*, 1960). In those trials New Zealand White rabbits, weighing about 3 lb at the beginning and about 6 lb at the end of the trials, were given pelleted diets containing 12 to 19 per cent crude protein in the air-dry diet. As judged by weekly weight gain and efficiency of feed utilisation the requirement of crude protein was between 13 and 14 per cent of the air-dry ration. A digestibility study showed that one of the diets which had 14 per cent crude protein contained 9·4 per cent digestible crude protein. With that amount of protein, average weekly gains equalled or exceeded the average expected gain postulated in the N.R.C. report. Rabbits given a diet containing 12 per cent crude protein ate less, gained less and utilised feed less efficiently than rabbits given diets with 13 per cent or more protein.

Requirements of fat

Wooley and Mickelson (1954) in a 4-week study of growth of rabbits on purified diets containing different levels of fat were unable to evaluate the influence of fat content of diet on growth. Thacker (1956) gave groups of rabbits stock diet or experimental diets of Ruffex 10, crude casein 25, maize oil 2, major minerals 5, trace elements 0·1 per cent differing in that hydrogenated oil was 3 to 23 per cent and total fat thus 5 to 25 per cent with dextrin adjusted accordingly. A vitamin mixture was added in such amounts that the diets with 5 to 20 per cent fat contained from 75 to 93 per cent of the amount of mixture added to the diet with 25 per cent fat. Weight gains with 10 to 25 per cent fat resembled those with stock diet. With 5 per cent fat final weight at the end of the 15 weeks of experiment was about 200 g less than that of rabbits on stock diet. Rabbits given diets with 10 per cent or more fat ate more feed than those given the diet with 5 per cent fat. Weight gain per g feed eaten was greater on all the experimental diets than on the stock diet.

Requirements of fibre

Failure of early attempts to produce purified rations adequate for growth and survival of rabbits indicated that the diets used were deficient in some

essential nutrient(s) or that their physical nature was not suited to the rabbit. Inclusion of cellulose or cellophane did not make them satisfactory and 15 per cent cellophane gave no better result than 3 per cent. This suggested that the diets were inadequate but did not exclude the possibility that in an otherwise adequate diet some roughage could be beneficial (Hogan and Ritchie, 1934). It has since been the practice to include some roughage such as Ruffex, cellulose or cellophane. In one study omission of the cellulose had no effect on growth of rabbits but addition of gum arabic or agar caused a significant improvement in growth (Hove and Herndon, 1957*b*). Abgarowicz (1948) studied the effect of ballast, i.e., undigested organic matter, on intake of dry matter and total digestible nutrients. Within the limits of the study the more ballast the greater was the intake of dry matter and intake of total digestible nutrients tended to be constant and independent of the amount of ballast.

In normal rations the fibre in feeds is the main source of undigested organic matter. According to Eriksson (1952) net availability of metabolisable energy in maintenance rations for rabbits is independent of crude fibre content and in fattening rations increases when the crude fibre content of the dry matter is raised from 4 to 19 per cent. He did not study very high levels of fibre content but concluded that the increase in net availability could not continue up to the highest possible crude fibre level and that there must be an optimum level, possibly between 14 and 19 per cent. It should be pointed out that the concept of an optimum fibre content where the net availability of metabolisable energy is maximum, as propounded by Axelsson for cattle, has not found general acceptance (Blaxter, 1950).

There would seem to be little evidence to guide us in choosing the desirable fibre content of a diet other than an assessment of the fibre content of diets upon which rabbits thrive. We have calculated that the fibre content of commonly recommended diets ranges from about 10 to 16 per cent of dry matter for does with litters and about 15 to 26 per cent for other rabbits. A pelleted feed which is said to be satisfactory for all classes of rabbits contains about 13 per cent.

Requirements of vitamins

Vitamin A

Rabbits need vitamin A for normal growth, development and reproduction. Under natural conditions the rabbit derives its vitamin A from green feed in the form of the carotene precursors. Good hay and dried green feed such as grassmeal and alfalfa retain appreciable amounts of carotene and are the principal sources of the vitamin in commonly prescribed winter rations and complete pelleted feeds. Diets made up of cereals such as white maize, oats and wheat feed, oil seed meals, meatmeal, tankage, beet pulp and dried yeast contain no detectable amount of carotene. Young rabbits given such diets show the usual signs of vitamin A deficiency which include xerophthalmia, keratinisation of mucous membranes, incoordination, retarded growth and extensive degeneration of the nervous system. Fully grown does given such diets may show no sign of acute vitamin A

deficiency but concentrations in plasma and liver fall and reproduction is adversely affected. Fewer living foetuses and more resorption sites are found towards the end of gestation than in normal does, and young which survive may show xerophthalmia and hydrocephalus. Xerophthalmia may appear also in the does after parturition (Nelson and Lamb, 1920; Nelson, Lamb and Heller, 1922*a*,*b*; Mellanby, 1934, 1935; Hetler, 1934; Rao, 1936; Phillips and Bohstedt, 1938; Perlman and Willard, 1941; Mann, Pirie, Tansley and Wood, 1946; Pirie and Wood, 1946; Millen, Woollam and Lamming, 1953, 1954; Lamming, Woollam and Millen, 1954; Lamming, Salisbury, Hays and Kendall, 1954; Millen and Woollam, 1956). The effect of vitamin A deficiency and the interdependence of the actions of vitamins A and E on the genital system of the male rabbit have been studied by French workers (Chevrel and Cormier, 1948*a*,*b*,*c*).

The requirement of carotene or vitamin A is not known. Mellanby found that 1 to 3 mg carotene daily prevented the appearance of signs and in the experiments of Phillips and Bohstedt 50 μg carotene daily was protective. Mellanby cured vitamin A deficiency by giving cabbage. In studies of eye lesions it was found that 500 to 1000 I.U. vitamin A in oil was curative (Mann *et al.*, 1946; Pirie and Wood, 1946). Pirie and Wood observed that plasma vitamin A concentration rose much more when green feed was given than when at least as much vitamin A equivalent in oil was given. In the experiments of Lamming, Salisbury *et al.* (1954) does given a supplement of 7500 μg vitamin A acetate weekly had at 16 to 28 days 6·1 living foetuses and only 0·5 resorption sites compared with 1·9 and 3·3 in deprived does. A rough calculation has been made of the carotene content of some recommended rations based on the average carotene values given in recent tables of feed composition (National Research Council, Committee on Animal Nutrition, U.S.A. and National Advisory Committee on Agricultural Services, Committee on Animal Nutrition, Canada, 1959). Winter rations without fresh greens, containing clover hay with or without timothy hay and a little yellow maize meal with or without a little alfalfa meal, for rabbits of $2\frac{1}{2}$ to 3 kg weight provide on average 2900 to 3900 μg carotene and the N.R.C. rations for growth or growth and fattening, containing alfalfa hay or alfalfa hay and alfalfa meal, provide about 7700 to 9600 μg carotene for a 3-kg rabbit. These calculations are based on average values for carotene content. It is possible that with hay of poor quality intakes would be much lower and in the absence of knowledge of the requirement of the rabbit it is perhaps wise to add a supplement of vitamin A to winter rations of doubtful potency. Cod liver oil is sometimes given as a source of vitamin A. The need for caution in the use of cod liver oil is discussed below.

Vitamin D

Rickets has been produced experimentally in young rabbits by depriving them of sunlight and giving them diets low in vitamin D and high in calcium (Goldblatt and Moritz, 1925; Mellanby and Killick, 1926; Moritz and Krenz, 1930; Jarl, 1948). The rachitogenic diets were either purified diets or mixtures of cereal and cereal by-products to which calcium was added. Such diets bear no resemblance to those commonly used in

rabbit feeding and, indeed, rickets is rarely seen in rabbits. In 9 years at a centre where 2000 or more rabbits had been bred Wilson (1935) saw rickets in only three. Early experience with rex-furred rabbits was that such rabbits were more susceptible to rickets than other breeds (Nachtsheim, 1931; Wilson, 1935). When rickets did occur it was usually in fourth or later litters and usually in large litters (Wilson, 1935).

The possible need for vitamin D supplements to rabbit rations was studied by Jarl (1948). A diet of alfalfa meal, dried sugar beet pulp and concentrates, with or without fish oil as additional source of vitamin D, was given to does during pregnancy and lactation and to their young after weaning. The additional vitamin D made no difference to growth of young. X-ray photographs of the tibia showed slower calcification in the young given no vitamin D supplement, but at 12 weeks in one experiment and 8 weeks in another there was no difference in calcification with or without the supplement. In one experiment the Ca : P ratio was about 1·4 : 1, in the other it was 9·1 : 1. In this study substantial amounts of alfalfa meal were eaten daily, about 98 g in pregnancy, 240 g in lactation and 57 g by young after weaning. Different results might be obtained with diets in which the roughage was a poor source of vitamin D. To be on the safe side some breeders include a little cod liver oil in the diet.

Vitamin E

About thirty years ago a condition of muscular dystrophy leading to paralysis was described in young rabbits given a diet treated with ether and ferric chloride. The diet consisted of rolled oats, wheat bran, casein, lard, cod liver oil, sodium chloride and calcium carbonate. Skimmed milk powder was added after the diet had been treated with ferric chloride (Goettsch and Pappenheimer, 1931).

It was observed also that certain purified diets containing lard and 1 or 2 per cent cod liver oil, including Goettsch and Pappenheimer's original diet untreated with ferric chloride, produced muscular dystrophy in rabbits. The condition arose also with a diet consisting of alfalfa hay and a grain mixture with 5 per cent cod liver oil, 1 ml placed on 20 g grain or placed directly into the mouth. The muscular dystrophy was cured by administration of vitamin E. α-Tocopherol given by mouth or parenterally was effective, dl-α-tocopheryl acetate was effective by mouth but not when given parenterally (Woodward and McCay, 1932; McCay, Madsen and Maynard, 1933; Morgulis and Spencer, 1936; Madsen, 1936; Turner, Meigs and Converse, 1936; Morris, 1939; Mackenzie and McCollum, 1939, 1940; Mackenzie, Levine and McCollum, 1940; Vivanco, 1941). In a study of rabbits with muscular dystrophy on a vitamin E deficient diet containing lard Bragdon and Levine (1949) observed myocarditis. The ill effects of a diet containing lard and cod liver oil become more pronounced when the diet is allowed to stand before use. The deterioration can be prevented by the use of suitable stabilisers against oxidative rancidity (Mattill and Golumbic, 1942). According to Meunier, Vinet and Jouanneteau (1947), who used hake liver oil, the harmful effect of the fish liver oil could be produced by the fatty acids of the oil and to some extent by the unsaponifiable fraction alone.

Muscular dystrophy has been described also in young rabbits given a diet almost free of fat and with carotene and calciferol in place of cod liver oil. Administration of α-tocopherol by mouth protected the rabbits against dystrophy but when cod liver oil was given as well as α-tocopherol, 2 ml cod liver oil mixed with the diet or 1 ml by mouth soon after the tocopherol supplements, the rabbits were not protected against muscular dystrophy (Mackenzie, Mackenzie and McCollum, 1941). The severity of the condition produced by a low-fat diet not containing cod liver oil was less than when cod liver oil was given and this observation is in agreement with the finding of Eppstein and Morgulis (1940) that rabbits given a low-fat diet with no cod liver oil but a few drops of percomorph oil and linseed oil required less tocopherol to protect them against dystrophy than did rabbits given a diet with lard and cod liver oil. Cavanagh and Macdonald (1958) expressed the view that although a syndrome superficially resembling vitamin E deficiency can be produced in rabbits on a fat-free diet, there is reason to believe that deficiency of vitamin E plays little or no part in it. They reached that conclusion from a study of the incidence of paralytic weakness and of nerve and muscle lesions in two groups of ten rabbits on a fat-free diet, one group given injections of α-tocopheryl acetate, the other not. In the group given tocopheryl acetate three showed paralytic weakness, two showed nerve lesions and two showed muscle damage. In the group given no supplement one showed paralytic weakness. This rabbit and four others showed nerve lesions and all but one had muscle lesions. It is a pity that the acetate was not given by mouth since it has been shown to be more protective given that way than parenterally.

Selenium has been found to have a beneficial effect in some forms of vitamin E deficiency in other species but not in muscular dystrophy of rabbits (Draper, 1957).

The practical implications of the results of studies of muscular dystrophy in the rabbit are that fats or fatty acids which are likely to become rancid should not be included in ready-made diets unless suitable stabilisers are included also. Instances of the occurrence of muscular dystrophy in rabbits reared on some pelleted feeds (Milman and Milhorat, 1953; Innes and Yevich, 1954; Short and Gammage, 1959) are discussed on p. 7. Some breeders include $\frac{1}{2}$ to 1 per cent cod liver oil in mash. The oil should be given fresh daily and not mixed in the mash for storage. The danger of giving larger amounts of cod liver oil has been clearly shown.

There is some evidence that hepatic coccidiosis may cause deficiency of vitamin E. It was suggested that the hepato-biliary infection might impair absorption of the vitamin (Diehl, 1960) but this was excluded by the results of a later study (Diehl and Kistler, 1961).

It is not certain whether or not vitamin E deficiency affects reproduction in the rabbit. Mackenzie (1942) subjected young rabbits to repeated episodes of muscular dystrophy separated by periods of cure with administration of α-tocopherol. No sign of testicular degeneration was seen in any male rabbit. On the other hand in mature rabbits deprived of vitamin E Chevrel and Cormier (1948*b*) detected changes in the testicles at autopsy which were similar to those seen in the early stages of vitamin E deficiency in the rat. They concluded that the later effects of deficiency on

the testicles are not usually seen in the rabbit because it dies before the changes have time to develop. A similar view was expressed by Pappenheimer (1948). He succeeded in showing in a few guineapigs that the testis does degenerate finally, just as in rats, and that in pregnant females on an inadequate intake the foetus dies about the middle of gestation. Pappenheimer found that when soya bean oil meal replaced lard in a dystrophy-producing diet for rabbits the mother might remain healthy but the young might be born dead or survive but a few days. Muscular dystrophy was found to have developed late in intrauterine life. It is of interest that a pelleted diet which gave trouble, apparently because of rancidity, caused reproductive failure as well as some instances of muscular dystrophy (Short and Gammage, 1959) although the specific cause of the reproductive failure was not established. In studies showing improvement in fertility and general condition in rabbits given supplementary feeds rich in vitamin E (Maiocco, 1936; Schioppa, 1936) there is no certainty that vitamin E specifically was responsible for the improvement.

Attempts have been made to assess the minimum vitamin E requirement of the rabbit by measuring the amount needed for prevention and cure of muscular dystrophy. Eppstein and Morgulis (1940, 1941) found that with a semi-purified diet containing 8 per cent lard and 2 per cent cod liver oil, 0·2 to 0·4 mg α-tocopherol per kg bodyweight was needed and less when cod liver oil was excluded. In a study of choline deficiency (Hove, Copeland, Herndon and Salmon, 1957) it was found that choline-deficient rabbits required 1·16 mg dl-α-tocopheryl acetate per kg per day as compared with a requirement of 0·44 mg by rabbits given a supplement of choline.

Vitamin K

Vitamin K does not seem to be required for normal growth of rabbits but is necessary for successful reproduction (Hogan and Hamilton, 1942). Females deprived of vitamin K show no difference in blood prothrombin from those given vitamin K (Adams, 1942) but they abort and placentae from aborted foetuses show haemorrhage in the decidual plates. Vitamin K prevents the abortion (Moore, Bittenger, Miller and Hellman, 1942).

Vitamin C

There is good evidence that rabbits on diets lacking vitamin C grow as well and remain as healthy as rabbits on the same diets supplemented with ascorbic acid (Hogan and Ritchie, 1934; Kalninš, 1946; Wooley, 1954; Harris, Constable, Howard and Leader, 1956). Nelson, Lamb and Heller (1922*a*) showed that rabbits grew and developed normally on diets upon which guineapigs showed signs of scurvy.

Bruce and Parkes (1946) found that rabbits grew well on a diet containing no fresh green feed and growth was not improved by the addition of ascorbic acid. In the studies of Kalninš (1946) and Harris *et al.* (1956) rabbits not only grew well and showed no sign of scurvy when their diets contained no vitamin C but the ascorbic acid content of their organs was

normal. Harris *et al.* (1956) suggest that a likely explanation of the appearance of supposed signs of scurvy reported in the literature, e.g., by Mellanby and Killick (1926), was that the experimental diets were deficient in other respects.

Vitamins B

It is now well established that the rabbit can synthesise vitamins of the B complex. Probably the first indication of this was the observation of Baglioni (1936) that urine from rabbits on a diet lacking vitamin B_1, when given to pigeons on a diet of polished rice, protected the pigeons against beriberi. Later it was shown that rabbits given a purified diet to which no biotin, folic acid, pantothenic acid or riboflavin was added excreted much more of these vitamins than was obtained from the diet (Olcese, Pearson and Schweigert, 1948). Excretion of folic acid, but not of the other vitamins, was reduced by inclusion of 1 per cent Sulfasuxidine in the diet. The reduction of excretion in the urine of folic acid when a sulphonamide was added to the diet was confirmed in another study (Simpson, Schweigert and Pearson, 1949). Nicotinic acid (Swaminathan, 1942; Olcese, Pearson and Sparks, 1949) and vitamin B_{12} (Kulwich *et al.*, 1953) also were excreted in amounts substantially above intake. Rosenthal and Cravitz (1958) observed that restriction of feed intake did not influence the concentration of vitamin B_{12} in the faeces and found a large amount of vitamin B_{12} in the urine of rabbits on a diet almost devoid of vitamin B_{12}.

The soft faeces of the rabbit contain more than do the hard faeces of the excreted vitamins riboflavin, pantothenic acid and vitamin B_{12} (Kulwich *et al.*, 1953), nicotinic acid (Scheunert and Zimmerman, 1952; Kulwich *et al.*, 1953), vitamin B_1 (Scheunert and Zimmerman, 1952) and vitamin B_6 (Hove and Herndon, 1957*a*). The soft faeces are eaten by rabbits free to practice coprophagy and so the total turnover of B vitamins may be several times the amount provided by the diet.

The satisfactory growth of rabbits on a diet lacking vitamin B_1 (Passmore, 1935) and of rabbits on purified diets low in biotin, riboflavin and pantothenic acid (Olcese *et al.*, 1948) and low in folic acid (Olcese *et al.*, 1948; Simpson *et al.*, 1949) suggests that the rabbit synthesises enough of these vitamins to make it independent of a dietary supply. It would seem, however, that on purified diets with casein as sole protein and a very low content of nicotinic acid rabbits do not thrive unless the diet is supplemented with nicotinic acid or its precursor the amino acid tryptophan (Wooley and Sebrell, 1945; Wooley, 1947; Olcese *et al.*, 1949). Rabbits given free tryptophan grew much better than those given the extra tryptophan as casein (Olcese *et al.*, 1949). Wooley and Sebrell (1945) gave rabbits graded supplements of nicotinic acid in a purified diet with casein as protein and low in nicotinic acid and found that growth improved as the supplement was increased to 10 mg per kg bodyweight daily. Deaths occurred only in rabbits given 1 mg per kg or less. Those estimated requirements obtained with a purified basal diet containing casein as sole protein may not apply to rabbits given other diets. Swaminathan (1942) used a diet of extracted oats, milk, casein, sugar and salts which supplied 0·1 mg nicotinic acid daily to rabbits of 1·3 to 1·5 kg weight and found that they

remained in good health and gained weight as well as those given the diet with a supplement of 3 mg nicotinic acid daily. A high intake of nicotinamide, 1 or 2 per cent of a dry diet, is not harmful to the rabbit (Handler, 1944; Randoin and Causeret, 1950).

Hove and Herndon (1957*a*) from a study of rabbits stanchioned to prevent coprophagy and given a diet with graded amounts of vitamin B_6 concluded that there is little synthesis of vitamin B_6 in the digestive tract of the rabbit and that vitamin B_6 in faeces is principally of dietary or metabolic origin. Under the conditions of their experiment the requirement of vitamin B_6 was calculated to be about 39 μg daily. Skin and neurological signs of vitamin B_6 deficiency were similar to those seen in rats and pigs.

Requirements of choline

Published reports of the experimental production of dietary necrosis of the liver in rabbits, sometimes attributed to deficiency of choline, led to a detailed investigation of the effects of severe choline deprivation (Hove, Copeland and Salmon, 1954). Weanling rabbits were given a diet of, per cent, methanol-extracted groundnut meal 30, purified casein 6, salts 4, sucrose 29·9, cystine 0·1, Ruffex 10, lard 19 and cod liver oil 1. The diet was supplemented with vitamins of the B complex, vitamin K and vitamin E but did not support growth and the deprived rabbits had fatty livers and hepatic cirrhosis. The diet contained 0·006 per cent choline. When that was supplemented with 0·12 per cent choline chloride growth was excellent. No further improvement in growth was obtained when the supplement was 0·2 per cent but 0·04 per cent was not enough. Taking into account the choline content of the basal diet and the effective supplement the conservative estimate of the choline requirement of the rabbit on the diet used was 0·13 per cent of the diet. Adult rabbits given the deficient diet lost weight and died with severely fatty livers.

The earlier the rabbit received the diet the longer it lived and the more severe the cirrhosis. All surviving choline-deficient rabbits developed progressive muscular dystrophy after 70 to 100 days (Hove and Copeland, 1954). Vitamin E deficiency was ruled out by the large amount of vitamin E in the basal diet and the levels of tocopherol in plasma and tissues. Choline added to the diet quickly cured the dystrophy. A supplement of 0·3 per cent betaine hydrochloride improved growth and prevented death and muscle damage but did not prevent heart and liver damage (Hove *et al.*, 1957).

Requirements of minerals

It is generally considered advisable to supplement all-vegetable rations with common salt and with bonemeal, lime or other source of calcium if cereals predominate in the ration. Such supplements are considered unnecessary if the ration contains fishmeal (Sandford, 1957; Wilson, 1959). In the National Research Council, U.S.A. report on nutrient requirements of rabbits the view is expressed that the rations described as examples of diets meeting the recommended allowances of energy and protein appear to be adequate in minerals other than salt. We have calculated the

Table 34

Estimated average content of minerals in some N.R.C. recommended rations

Diet	Amounts lb	Amounts g		Ca g	Co mg	Cu mg	Fe mg	Mg g	Mn mg	P g	K g	Na g	Zn mg
Growth (av. 6½ lb rabbit)													
Alfalfa hay	0·28	127		2·08	0·017	1·74	30	0·41	6·6	0·33	2·25	0·20	2·2
Oats	0·064	29	73	0·03	0·002	0·19	2	0·06	1·2	0·11	0·12	0·02	
Barley	0·064	29		0·03	0·003	0·25	2	0·04	0·5	0·14	0·18	0·01	0·5
Soya bean oil meal pellets	0·032	15		0·05	0·001	0·53	2	0·04	0·4	0·10	0·30	0·05	
		200		2·19	0·023	2·71	36	0·55	8·7	0·68	2·85	0·28	2·7
		Per 100 g		1·1	0·01	1·35	18	0·28	4·4	0·34	1·42	0·14	1·4
Composition of ration excluding hay		73		0·11	0·006	0·97	6	0·14	2·1	0·35	0·60	0·08	
		Per 100 g		0·15	0·008	1·33	8	0·19	2·9	0·48	0·82	0·11	
Pregnancy (10 lb doe)													
	lb	g											
Alfalfa hay	0·25	114		1·87	0·015	1·55	27	0·36	5·9	0·30	2·02	0·18	1·9
Barley	0·054	24		0·02	0·003	0·21	1	0·03	0·4	0·11	0·15	0·00	0·4
Sorghum grain	0·054	24		0·01	0·008	0·26	1	0·05	0·4	0·08	0·09	0·01	0·4
Soya bean oil meal pellets	0·032	15		0·05	0·001	0·53	2	0·04	0·4	0·10	0·30	0·05	
		177		1·95	0·027	2·55	31	0·48	7·1	0·59	2·56	0·24	2·7
		Per 100 g		1·1	0·015	1·44	18	0·27	4·0	0·33	1·45	0·14	1·5
Lactation (10 lb doe, litter of 7)													
	lb	g											
Alfalfa hay	0·24	109		1·79	0·014	1·49	26	0·35	5·6	0·28	1·93	0·17	1·8
Wheat	0·343	156		0·09	0·014	1·27	9	0·28	8·5	0·64	0·90	0·16	2·4
Sorghum grain	0·123	56		0·03	0·017	0·60	3	0·11	0·9	0·20	0·21	0·03	0·9
Soya bean oil meal pellets	0·414	188		0·60	0·017	6·83	24	0·51	5·2	1·26	3·70	0·64	
		509		2·51	0·062	10·19	62	1·25	20·2	2·38	6·74	1·00	5·1
		Per 100 g		0·5	0·012	2·0	12	0·25	4·0	0·47	1·32	0·20	1·0

mineral content of some N.R.C. rations on the basis of average values given in the Joint United States—Canadian Tables of Feed Composition (National Research Council, Committee on Animal Nutrition, U.S.A. and National Advisory Committee on Agricultural Services, Committee on Animal Nutrition, Canada, 1959). The results are presented in Table 34. It will be seen that in the rations for growing and for pregnant rabbits alfalfa hay is the principal single source of all the minerals. In the ration for lactating does the large quantity of soya bean oil meal contributes more than, or as much of all minerals except calcium as does hay. These values for mineral content of rations are average values. It is possible that rabbits fed on locally grown feeds in areas where pasture or crops are deficient in certain minerals would have a much lower intake of those elements. There is evidence, for instance, that rabbits in the Stanislav area of Russia benefit from the addition of a trace element mixture to the diet (Homutova, 1957). Feeding trials with feeds low in phosphorus and manganese are described below.

It has been possible to calculate from Butterfield's (1929) published figures for minerals in milk the amounts secreted by a doe, at the peak of lactation, yielding 207 g milk per day. These amounts are compared in Table 35 with the daily intake of minerals from the N.R.C. ration for a lactating doe.

Table 35

Minerals in rabbit's milk and diet

		Ca	Fe	Mg	P	K	Na
In milk	g daily	1·32	0·00	0·07	0·90	0·43	0·30
In diet	g daily	2·51	0·06	1·25	2·38	6·74	1·00

Calcium

The calculated percentage content of Ca in the N.R.C. rations is 1·1 for growing and pregnant rabbits and 0·5 for lactating does. If hay were omitted from the ration for growing rabbits the percentage content of Ca would fall to 0·15. Light and Frey (1941) reported the development of spontaneous vertebral fractures in rabbits on a diet containing 0·2 per cent Ca. Swan and Salit (1941) reported opacity of the eye lens, tetany and a low blood serum calcium in rabbits on an intake of 0·08 mg Ca per day. An intake of 30 to 60 mg Ca daily protected against lens opacity and tetany.

As has been stated above it is generally agreed that diets in which cereals predominate should be supplemented with calcium. The percentage of Ca in the N.R.C. ration for lactating does is lower than that of rations for growing and pregnant rabbits although the total daily supply is 2·5 g compared with 2 g for growing and pregnant rabbits. It would be of interest to discover if any benefit would accrue to mother or young from a supplement of calcium. The pelleted Diet SG1 of Short and Gammage (1959) contains fishmeal and has a calculated Ca content of 1·1 per cent. The giving of hay with this pelleted diet would not reduce the percentage Ca content or would reduce it only slightly according to the quality of the hay. An investigation of the optimum calcium content of diets for rabbits seems overdue.

Phosphorus

The N.R.C. ration for growing rabbits contains 63·5 per cent alfalfa hay and 36·5 per cent of a mixture of oats, barley and soya bean oil meal pellets. According to our calculation of phosphorus content, based on average values, the alfalfa hay has 0·26 per cent P and the whole ration has 0·34 per cent P. Heinemann, Ensminger, Ham and Oldfield (1957) compared the growth, reproduction and body composition of New Zealand White rabbits given a pelleted diet containing 86 per cent alfalfa hay from land deficient in P or from the same land fertilised with phosphate. The hays contained 0·12 and 0·26 per cent P, respectively. The other ingredients of the pelleted diet were cane molasses 9 per cent, unenriched white flour 5 per cent and vitamins. The P contents of the pelleted diets were 0·12 and 0·18 per cent, respectively. Differences observed as a result of feeding the low-P hay were significantly retarded growth, lower mature bodyweights, higher number of services required per conception, significantly higher levels of Ca, P, fat and ash in skeletons of 10-week-old animals and significantly lower levels of ash in skeletons of mature animals, extremely low breaking strength of the humerus and abnormal bone structure as revealed by X-ray photographs. There was no difference in serum inorganic phosphorus. Difference in weight gain might have been due in part to difference in protein content of the diets which was 11·81 per cent in the high-P ration and 10·89 per cent in the low-P ration. Average daily gain on both diets was lower than normal for well nourished rabbits of the breed. It should be noted that if the N.R.C. ration were made up of hay containing only 0·12 per cent P the whole ration would contain 0·25 per cent P because of the contribution of the remainder of the ration unless the other ingredients also had P contents lower than average.

In a study of the effect of phosphate fertiliser on dried soya forage for rabbits, Matrone, Weldon, Smart, Sherwood, Smith and Wise (1954) found that when rabbits of the Dutch breed were given a diet of soya forage 76, cerelose 13, egg albumin 6 and Wesson oil 5 per cent with vitamins they made smaller gains, had a lower concentration of inorganic phosphorus in serum and bones of greater fragility when the soya forage contained 0·106 per cent P on a moisture-free basis than when fertilised forage containing 0·144 per cent P on a moisture-free basis was used. A supplement of calcium phosphate added to the diets eliminated these differences. Since the extra phosphate produced no improvement in the high-P diet it was concluded that the P content of the high-P forage, which was 0·164 per cent of dry matter in this instance, was adequate. This would be equivalent to a P content of 0·154 per cent in alfalfa hay of 6 per cent moisture as used by Heinemann *et al.* (1957) and 0·144 per cent in alfalfa hay of 12 per cent moisture, the moisture content assumed in our analysis of the N.R.C. ration.

Iron and copper

Rabbit's milk like cow's milk contains little iron. The stores of iron in the liver of the young fall steeply from the very high levels at birth and young rabbits at the end of the suckling period may be anaemic (Lintzel and

Radeff, 1931; Spray and Widdowson, 1950). Diets of cow's milk have been used to produce anaemia experimentally in rabbits. Hart, Steenbock, Elvehjem and Waddell (1925) found that iron alone was not curative but iron and cabbage was. Smith, Medlicott and Ellis (1944*a*) showed that the anaemia, which was hypochromic and microcytic, was not cured by iron alone or by copper alone but in a few rabbits given both 2 mg Fe and 0·2 mg Cu daily there was rapid haemoglobin regeneration. Later it was shown that other signs of copper deficiency in the rabbit are greying of black hair, loss of hair, dry scaly skin and retarded growth (Smith and Ellis, 1947*a*). A study of the Cu content of the liver of rabbits at birth and at intervals thereafter (Lorenzen and Smith, 1947; Spray and Widdowson, 1950) showed that concentration fell during the suckling period, rose only slightly at about 2 months and in the adult rabbit remained below that of newborn rabbits.

The optimum requirements of iron and copper have not been established but it may be noted that the amounts which caused rapid haemoglobin degeneration in deprived rabbits and, in the case of copper, prevented hair and skin changes, were very small compared with the amounts provided by the N.R.C. diets. The toxic effects of an excess of molybdenum in experimental diets, 0·1 per cent or more, may be counteracted by increasing intake of copper (Arrington and Davis, 1952, 1953) but we have seen no report of excess intake of molybdenum by rabbits on ordinary diets.

Manganese

According to the findings of Lorenzen and Smith (1947) liver stores of manganese, unlike those of copper, are not high at birth and there is no drop during the suckling period corresponding to the drop in liver copper concentration. When rabbits are weaned to a diet of cow's milk supplemented with iron and copper gross bone deformity develops and growth is retarded unless a supplement of manganese is given (Smith, Medlicott and Ellis, 1944*b*; Ellis, Smith and Gates, 1947). A daily supplement of 0·3 mg Mn prevented obvious signs of deficiency but storage of manganese in the liver and growth improved when the supplement was 1·0 mg. A supplement of 4 mg gave better growth than 1 mg in one experiment but not in another so the optimum intake was not clear (Smith and Ellis, 1947*b*). A recent study of the feeding of rabbits for three generations on a basal diet of hay and potatoes grown on soil deficient in manganese suggests that 1 mg Mn is ample (Roth, 1960). Over the three generations studied mean daily intake of Mn of rabbits on the basal diet was 0·93 mg, 0·5 mg for young rabbits and 1·1 mg for adults. In growth, appearance or vitality, length or weight of bones and manganese content of tissues there was no difference in any generation between groups given only the basal diet and groups given the basal diet supplemented with manganese. Mean intake of Mn of the group given the supplement was 5·05 mg, 3·8 mg for young and 9 mg for adult rabbits. Roth calculated from the mean Mn content of the body that even from the low-Mn diet less than 1 per cent of the Mn was retained.

In the study of Smith and Ellis (1947*b*) rabbits given 8 mg per head daily grew less well than those given 1 mg Mn, so it was thought that 8 mg might be on the border of toxicity. There is no evidence that an intake of

8 mg Mn in ordinary diets is harmful. The calculated content of the N.R.C. rations is of this order and that of the ration for the lactating doe is about 20 mg. It has been shown that a concentration of 2000 p.p.m. Mn in the diet depresses haemoglobin regeneration in anaemic rabbits (Matrone, Hartman and Clawson, 1959). But that is a very high concentration, about fifty times the estimated Mn content of the N.R.C. diets.

Cobalt

The average intake of cobalt from the N.R.C. ration for growing rabbits is calculated to be 23 μg. It has been shown, however, that growth and mortality in rabbits given a diet of milk and maize grown in a low-cobalt area were not significantly improved by the giving of a supplement of 4 μg Co daily. The mean Co intake from the diet was less than 0·1 μg and it was concluded that the rabbit requires less than this amount (Thompson and Ellis, 1947) if it requires any.

Magnesium

Poor growth, hyperirritability leading to convulsions and death have been described in rabbits on a purified diet low in magnesium. From studies with graded supplements of magnesium it was concluded that the Mg requirement of the rabbit is between 30 and 40 mg per 100 g diet when the magnesium is given as sulphate (Kunkel and Pearson, 1948). The average Mg content of the N.R.C. diets is about 250 mg per 100 g.

Potassium

Reference has already been made to muscular dystrophy in rabbits deprived of vitamin E or of choline. It has been produced also by restricting the potassium content of purified diets to 0·3 per cent or less. The basal diet of extracted casein 20, sucrose 57, cellulose 10, lard 6, cod liver oil 2, minerals 5 per cent and a vitamin mixture did not support optimum growth even when supplemented with potassium. Maximum growth was obtained with between 0·6 and 0·9 per cent K (Hove and Herndon, 1955). This is in agreement with the observation of Wooley (1954) that a level of 0·8 per cent K was the minimum amount that produced maximum growth on a purified diet containing 20 per cent casein. The average K content of the N.R.C. diets is about 1·4 per cent.

Iodine

The iodine requirement of the rabbit is not known. Diets containing cod liver oil or fishmeal should contain ample. We have seen no report of the occurrence of iodine deficiency in rabbits fed on all-vegetable diets without a supplement of iodine so, with the possible exception of rabbits reared on crops grown in an iodine-deficient area, there would seem to be no need to supplement diets with iodine.

Sulphur

There is no evidence that the rabbit needs inorganic sulphur in addition to the organic sulphur provided by sulphur-amino acids in the dietary

protein although it has been demonstrated with radioactive sulphur that the rabbit can utilise sulphur given as sulphate for the synthesis of cystine and methionine (Kulwich, Struglia, Jackson and Pearson, 1954; Kulwich, Pearson and Lankenau, 1954). Very little of the radioactive sulphur appeared in the hair, which is in line with the known stability of sulphur in hair (Feaster and Davis, 1959). It used to be thought that sulphur had beneficial effects on skin and coat but improving results have not been demonstrated. Deficiency of methionine has been produced experimentally by giving oxidised casein as protein in a purified diet. Moderate weight loss, paralysis, muscle damage and death occurred but no mention is made of coat condition (Hove *et al.*, 1957). The requirements of the rabbit for sulphur-amino acids have not been established. Barrett, King and Pickard (1930) were unable to demonstrate any significant effect on growth of wool or its sulphur content of supplementing a low-cystine diet with cystine and Bortoli (1954) did not significantly increase yield of wool by giving rabbits bovine horn as supplementary source of cystine. Crampton and Finlayson (1935) found that a supplement of cystine and casein increased the growth-promoting value of unfertilised pasture grass but cystine alone was ineffective.

Salt

Lack of an adequate supply of salt causes loss of water from the body, low rate of growth, low milk production, and the health and condition of animals is profoundly affected. Utilisation of feed is impaired. Indeed, the effect on condition generally and on the coat in particular is so marked that it is surprising that more studies of the salt requirements of rabbits have not been made.

It is well known that herbivorous animals have a "salt hunger" and, under natural conditions, seek out "salt licks" to satisfy their craving. Observations made at Canberra show that the rabbit is no exception (Cook, 1932).

The tolerance of rabbits for salt is high. This has been shown by Gompel, Hamon and Mayer (1936) in experiments in which the feed was made into a mash with salted water. When the salt concentration exceeded 10 g per 100 ml, no other water being allowed, the feed was eaten with reluctance and when the salt exceeded 25 g per 100 ml the feed was refused. If the concentration was gradually increased the rabbit acquired tolerance and readily took feed containing up to 35 g per 100 ml. Rabbits given salty feed and offered unsalted water increased water consumption so that the final concentration of salt was less than would depress feed consumption. The maximum daily quantity taken without increasing thirst was about 0·3 g.

Only one record has been found of the amount of salt eaten voluntarily by rabbits. Templeton (1938) measured the salt consumption of New Zealand rabbits fed on concentrates and hay with a small allowance of greenstuff and a salt lick. Ten mature males took on an average 0·088 lb yearly, or 0·88 per cent of their own liveweight, and 43 does with their litters 0·195 lb yearly. This is equivalent to 0·1 g daily for a buck and 0·24 g daily for a doe with a litter.

In North America salt is commonly added at a level of from 0·25 to 0·5 per cent of the total ration (Butterfield and Lloyd, 1935) or as 1·0 per cent of mash. Complete pellets made from plant foods usually include 0·5 per cent salt (Templeton and Kellogg, 1959) or 1 per cent (National Research Council, Committee on Animal Nutrition, U.S.A., 1954).

In the absence of further information as to the salt requirements of rabbits, it would probably be best to provide a salt brick, as is done for cattle and sheep, from which the rabbits can satisfy their requirement.

Requirements of water

More than two-thirds of the weight of the newborn rabbit, and about two-thirds of the adult, is water (Wilson and Morris, 1932; Widdowson, 1950). Water is constantly lost from the body in the excreta and through the skin. A lactating doe may lose as much as 200 g daily in milk. Water lost must constantly be replaced. The requirement will be increased in hot weather. Rabbits kept in the sun lose from 12 to 23 g of water per hour as compared with 2 to 3 g per hour in the shade (Hill, 1920). The effect of environmental temperature on feed and water consumption of New Zealand White rabbits was studied by Johnson, Ragsdale and Cheng (1957). The general picture emerging from a year's study of rabbits in environmental temperatures of 48°F or 83°F from the first week of life is that the higher temperature resulted in reduced feed intake, lower rates of weight gain, little change in daily water intake but increased intake of water per unit bodyweight. At both temperatures water intake per kg bodyweight declined with increasing age. Rabbits at 83°F drank about 120 ml per kg per day at 70 days of age and about 64 ml at 340 days. Corresponding figures at 48°F were about 76 ml decreasing to 46 ml per kg. When the temperature was raised to about 100°F the rabbits reduced their intake of water as well as of feed (Johnson, Cheng and Ragsdale, 1957). The feed of those rabbits was a dry pelleted diet.

Insufficient water supply leads to reduced feed intake and to weight loss (Gasnier, Gompel, Hamon and Mayer, 1932) and a fall in wool production (Wirth, 1933). Christian (1935–36) found that a diet of dry mash, 150 g, and green feed, 100 g, without water, caused death from impaction of the caecum. When water was given, 80 to 120 ml were taken daily.

The effect of the type of diet on water intake of five rabbits was studied by Brüggemann (1937). The results are summarised in Table 36.

There was considerable individual variation in intake among rabbits on the same diet but it may be deduced that rations of steamed potatoes or mangolds and hay provided enough water under the conditions of the experiments, that fresh green feed provided more than enough, and that dry rations of grain with or without hay required the addition of 100 to 156 ml, about a quarter of a pint of water daily. From a study of two rabbits Kennaway (1943) concluded that a rabbit weighing $2\frac{1}{2}$ kg, eating a dry diet, will take about 160 ml water or 65 ml per kg per day.

It will be seen from the tables of composition of recommended rations that the N.R.C. diets are of the dry type, providing only 10 to 20 ml water for growing and pregnant rabbits and 57 ml for the lactating doe. The

Table 36

Effect of diet on water intake
(Brüggemann)

Diet	Water contained in feed ml	Additional water drunk ml	Total water intake ml
Meadow hay	11	156	167
Lucerne hay	17	144	161
Nettle hay + steamed potatoes	156	—	156
Green lucerne	235	—	235
Maize silage + meadow hay	96	12	108
Oats	12	101	113
Barley + meadow hay	19	142	161
Wheat + meadow hay	19	121	140
Mangolds + meadow hay	202	—	202
Steamed potatoes + meadow hay	160	—	160

European diets contain succulent feeds and most provide between 200 and and 400 ml water daily.

Reference has been made already to the loss of water from the body when the intake of salt is insufficient and to the increased intake of water when salt consumption is excessive. It is best, therefore, to supply both salt and water independently of the feed and to allow animals to adjust to their own needs the intake of each.

Summary

The process of digestion in the rabbit is briefly described with special reference to the rabbit's habit of coprophagy. The rabbit does not digest fibre of roughage as well as do ruminants but there is little difference in ability to digest protein. A table of coefficients of digestibility of some rabbit feeds is presented and attention is drawn to the wide variation in digestibility of fibre of cereals reported by different workers. Investigation of possible reasons for the differences, such as the form in which the cereal is given and the age of the experimental animals, might be of value.

Choice of feed and method of feeding are discussed. Weight can be maintained on a diet of fresh green feed or a mixture of fresh clover and clover hay and on alfalfa hay alone but during pregnancy, lactation and early growth of the young, concentrates are needed to give the high levels of production needed for commercial rabbit rearing. Indeed most rations recommended for maintenance include some concentrates.

Complete pelleted diets are becoming popular, given with or without hay.

The content of water, crude fibre and digestible crude protein and the energy value of the digested feed, in calories, of some recommended rations have been calculated and are presented in a series of tables and a summary table. The data on composition and energy value of feedingstuffs used in the calculations are presented in an appendix.

A review of available evidence suggests that antibiotics have no significant effect on weight gain in the rabbit and are not associated with

improved feed conversion except in experiments in which high mortality is reduced by an antibiotic.

Rabbits reared primarily for meat in the United States are slaughtered at, or shortly after, weaning. The yield of dressed carcase and proportion of edible meat increases with increasing age at slaughter and the amount of feed required per pound of marketable liveweight increases rapidly. Prime carcases of fryer rabbits yield a higher proportion of edible meat than do lower grade carcases.

Little information is available about the effect of diet on yield of wool and quality of pelt.

A review of the literature on nutrient requirements shows that basal or standard metabolic rate has been measured and attempts have been made to calculate maintenance requirement of energy and the amounts needed for milk production and the putting on of weight by young rabbits. Nitrogen balance studies give some information on the nutritive ratio necessary for maintenance and there is some evidence as to the amount of protein required by growing, fattening New Zealand White rabbits. Studies with purified diets or diets of feeds deficient in a specific nutrient have been made in order to establish requirements of fat, fibre, choline, vitamins and minerals. These have yielded interesting information on the effects of specific deficiencies, tentative estimates of requirements of choline, vitamin E, manganese, magnesium and potassium and evidence that the rabbit does not require vitamin C and no more cobalt than is supplied by cobalt-deficient pasture. The requirement of vitamin E depends on the nature of the diet as indeed may the requirements of other nutrients. The rabbit appears to be able to synthesise vitamin B_1, riboflavin, biotin, pantothenic acid, vitamin B_{12} and nicotinic acid although with some diets there may be a need for nicotinic acid or its precursor, tryptophan. There is some evidence that the rabbit does not synthesise vitamin B_6. The amount of drinking water needed depends on the nature of the diet and the environmental conditions. We still do not know the optimum levels in the diet of fat, fibre, carotene or vitamin A, vitamin K, calcium, phosphorus, iron, copper and iodine nor do we know the requirements of the rabbit for sulphur-amino acids.

Appendix

The following table gives the composition of some feedingstuffs and their content of digestible nutrients as measured in trials with rabbits. Where experiment yielded a digestibility coefficient greater than 100 per cent the digestible nutrient was calculated on the assumption that all was digested and where the digestibility coefficient of fibre was negative it was assumed that none of the fibre was digested. Values for energy of the digested feed, except those of Voris *et al.* (1940) which were estimated by calorimetry, were calculated by us by application of the appropriate factors given by Merrill and Watt (1955). Nutritive ratios were calculated as the ratio of energy from digestible protein, obtained by multiplying digestible crude protein by the appropriate factor, to the remaining energy of digested feed.

Composition of some rabbit feeds

Feed	Percentage composition						Energy kcal per 100 g	Crude fibre in dry matter %	Digestible nutrients—per cent				Energy of digested feed (EDF) kcal per 100 g	Nutritive ratio	Reference
	Water	Crude protein	Ether extract	Crude fibre	N-free extract	Ash			Crude protein	Fat	Crude fibre	N-free extract			
Clover, green	80·3	2·8	0·8	3·3	9·8			16·8	2·1	0·6	2·1	7·8	59	1 : 3·9	Neseni and Scheven, 1958
Alfalfa (lucerne), green	78·5	4·5	0·9	5·3	8·6	2·2		24·7	3·9	0·6	2·9	7·0	69	1 : 2·1	Schürch, 1949
Mixed grasses with clover, dried	9·6	20·8	5·1	21·4	43·3	9·3		23·7	12·8	1·3	5·6	24·2	210	1 : 1·9	Watson and Godden, 1935
Clover hay	12·5	12·9	2·7	24·7	41·2	6·0	391	28·2	8·1	1·7	4·9	27·7	193	1 : 3·2	Voris *et al.*, 1940
Alfalfa (lucerne) meal*	6·5	20·4	2·2	20·4	42·1	8·4	420	21·8	16·5	0·4	6·1	34·5	271	1 : 1·9	,, ,, ,,
Alfalfa (lucerne) hay	11·4	17·9	1·5	30·9	32·4	5·9	412	34·9	12·9	0·2	5·6	20·5	189	1 : 1·6	,, ,, ,,
Meadow hay, medium quality	14·5	10·0	2·5	25·0	41·0	7·0		29·2	5·5	1·3	5·5	21·7	158	1 : 4·0	Schürch, 1949
good	12·4	13·6	3·0	23·5	39·3	8·2		26·8	6·8	1·4	7·8	21·6	175	1 : 3·5	,, ,,
Timothy hay	10·1	5·9	1·8	30·7	47·1	4·4	407	34·1	2·7	0·8	3·3	24·0	141	1 : 8·1	Voris *et al.*, 1940
Oat straw	14·0	3·8	1·8	39·7	36·4	4·3		46·2	1·1	0·5	9·9	12·7	106	1 : 15·3	Schürch, 1949
Marrowstem kale	86·1	2·1	0·3	2·5	7·2	1·8		18·0	1·8	0·2	1·4	6·3	43	1 : 3·8	Woodman, 1947; Watson and Horton, 1936
Fodder beets	85·4	1·0	0·1	0·9	11·6	1·0		6·2	0·7	0·1	0·9	11·1	55	1 : 14·7	Schürch, 1949
Carrots	87·7	1·4	0·1	1·2	8·7	0·9	48	9·8	1·2	0·1	0·7	8·5	44	1 : 6·3	Voris *et al.*, 1940
Potatoes, steamed	75·0	2·3	0·1	0·8	20·3	1·5		3·2	1·6	0·1	0·7	19·9	95	1 : 10·9	Schürch, 1949
Turnips	91·8	1·0	0·1	1·1	5·2	0·8	32	13·4	0·9	0·1	0·9	5·2	31	1 : 5·9	Voris *et al.*, 1940
Barley	14·5	10·7	1·2	6·4	65·0	2·2	388	7·5	9·1	1·2	0·8	58·0	320	1 : 5·0	Voris *et al.*, 1940
Maize	14·0	10·0	3·6	2·1	68·9	1·4	398	2·4	8·4	3·4	2·1	63·3	366	1 : 6·5	,, ,, ,,
Oats	11·8	10·5	4·9	11·1	58·5	3·2	—	12·6	8·5	4·5	2·1	46·2	294	1 : 5·0	Schürch, 1949
	12·1	10·9	4·2	10·6	58·9	3·3	418	12·1	8·6	4·1	0·0	46·4	291	1 : 4·8	Voris *et al.*, 1940
Sorghum	6·5	12·1	2·8	1·9	75·0	1·7	403	2·0	8·7	2·7	1·9	68·0	350	1 : 5·9	,, ,, ,,
Wheat	14·9	8·9	1·3	2·2	70·9	1·8	379	2·6	7·5	1·3	0·6	68·5	352	1 : 7·1	,, ,, ,,
Wheat bran	10·4	16·7	3·9	10·5	51·6	6·9	409	11·7	13·9	3·0	2·6	33·7	263	1 : 2·3	,, ,, ,,
Groundnut meal	6·0	42·8	7·7	4·4	32·6	6·5	457	4·7	39·0	7·7	2·2	31·4	422	1 : 0·9	Voris *et al.*, 1940
Linseed oil cake	11·7	33·3	6·8	8·2	34·1	5·9		9·3	29·0	6·6	1·9	26·6	349	1 : 1·1	Schürch, 1949
	10·8	36·8	4·0	7·8	35·2	5·4	429	8·7	31·8	4·0	1·6	28·5	341	1 : 0·9	Voris *et al.*, 1940
Soya bean oil cake	9·3	45·5	4·6	5·0	29·9	5·7	444	5·5	40·8	4·4	2·6	28·6	400	1 : 0·7	,, ,, ,,
Fishmeal	10·0	60·4	1·8	—	0·9	26·9		—	45·3	1·8	—	0·4	275	1 : 0·07	Schürch, 1949
Meat-and-bone meal†	9·7	50·3	15·0	—	1·0	24·0		—	37·7	15·0	—	0·5	357	1 : 0·7	Woodman, 1947
Milk, dried, skimmed	5·2	33·8	0·8	—	51·8	8·4		—	33·1	0·7	—	51·3	394	1 : 1·1	Schürch, 1949
Milk, dried, whole‡	4·2	25·5	26·5	—	37·4	6·4		—	25·5	25·2	—	35·2	514	1 : 2·6	Woodman, 1947
Milk, whole	87·7	3·4	3·5	—	4·6	0·8		—	3·4	3·3	—	4·3	67	1 : 2·5	Schürch, 1949
Milk, skimmed	90·3	4·0	0·2	—	4·7	0·8		—	3·9	0·2	—	4·7	42	1 : 0·9	,, ,,
Kitchen waste	88·0	1·9	1·0	1·1	6·7	1·3		9·2	1·3	0·8	0·6	5·4	39	1 : 5·0	Schürch, 1949

* Taken as alfalfa hay, 20% protein
† Digestibility coefficients taken as for fishmeal
‡ Digestibility coefficients taken as for whole milk

References

Abgarowicz, F. (1948). [Effect of ballast in the feeding of rabbits. Contribution to the calculation of the role of ballast in the nutrition of farm animals.] Juris-Verlag, Zürich.

Adams, W. (1942). [The behaviour of the prothrombin level in experimental animals on a vitamin K free diet.] *Klin. Wochenschr.*, **21**, 196.

Adolph, W. H., Macdonald, H. A., Yeh, H. L. and Lofgreen, G. P. (1947). Content and digestibility of morning and evening cuttings of alfalfa. *J. Animal Sci.*, **6**, 348.

Ambrosioni, P. and Masoni, S. (1955). [Experiments with healthy rabbits and rabbits infected with *Candida albicans* and treated with chlortetracycline (aureomycin). 1. Sensitivity of the rabbit to chlortetracycline and action of it on experimental mycosis. 2. Attempts at prophylaxis by giving vitamins and organisms of the enteric group.] *Boll. Ist. sieroterap. milan.*, **34**, 408; 418.

Ando, N., Kojima, M., Hetsuka, K. and Sera, H. (1956). Studies on the meat and by-products (46–48). Rabbit Part (12–14). *Bull. Fac. Agric. Univ. Miyazaki*, **1**, 237.

Anonymous (1960). *Fur and Feather*, May 18th, 465.

Arrington, L. R. and Davis, G. K. (1952). Molybdenum toxicity in the rabbit. *J. Animal Sci.*, **11**, 756.

Arrington, L. R. and Davis, G. K. (1953). Molybdenum toxicity in the rabbit. *J. Nutrition*, **51**, 295.

Axelsson, J. (1942). [Digestive capacity of hens and rabbits.] *Arch. Kleintierzucht*, **3**, 81.

Axelsson, J. (1949). Standards for nutritional requirements of domestic animals in the Scandinavian countries. *V^e Congrès Internat. Zootec., Paris.*

Axelsson, J. and Eriksson, S. (1953). Energy requirements for maintenance of domestic animals. Their measure and relationship to body weight. *Kungl. Lantbrukshögsk. Ann.*, **20**, 51.

Baglioni, A. (1936). [Resistance of individual rabbits to vitamin B_1 depletion and possibility of endogenous synthesis.] *Arch. Fisiol.*, **35**, 362.

Baker, F., Harriss, S. T., Phillipson, A. T., McNaught, M. L., Smith, J. A. B., Kon, S. K. and Porter, J. W. G. (1947). *Nutrition Absts. Revs.*, **17**, 1.

Baldissera-Nordio, C. (1952*a*). [Onion anaemia in several species of domestic animals.] *Arch. Tierernährung*, **2**, 309.

Baldissera-Nordio, C. (1952*b*). [The blood picture of the mother and of the foetus in onion anaemia. Importance of light for the blood picture of rabbits with onion anaemia.] *Boll. Soc. ital. Biol. sper.*, **28**, 1704; 1705.

Baldissera-Nordio, C. (1953). [Effect of vitamin B_{12} on onion anaemia.] *Zootec. Vet.*, **8**, 243.

Barboriak, J. (1953). [Effect of additions of fibre on the energy metabolism of the rabbit. Extension of the "value" system of Kellner.] *Thesis, Univ. Zürich.*

Barritt, J., King, A. T. and Pickard, J. N. (1930). The effects of cystine diet on keratin composition in rabbit wool. *Biochem. J.*, **24**, 1061.

Behm, G. (1954). [Effect of crude fibre in feed on the faecal loss of nitrogen in experiments on rats, rabbits and pigs.] *Arch. Tierernährung*, **4**, 197.

Benedict, F. G. (1938). Vital energetics. A study in comparative basal metabolism. *Carnegie Inst. Washington Publ.* 503.

Bertelli, E. (1936). Scientific management in rabbit breeding. 1. Method employed in the practical and scientific breeding of the rabbit, based on heredity and milk aptitude. *Monthly Bull. Agric. Sci. Practice*, **27**, 453T.

Bidone, D. (1933). Cases of abortion in the Angora rabbit. *Proc. 5th World's Poultry Congress, Rome.*

Blaxter, K. L. (1950). Energy feeding standards for dairy cattle. *Nutrition Absts. Revs.*, **20**, 1.

Bonadonna, T. and Pozzi, G. C. (1957). [Preliminary observations on changes in the endocrine glands of rabbits fed on *Brassica oleraceae* (cabbage) and *Brassica campestris* (rape).] *Folia endocrinol.*, **10,** 477.
Bortoli, O. (1954). [The effect of administration of hydrolysates of horn on the wool of the Angora rabbit.] *Riv. Zootec.*, **27,** 87.
Bragdon, J. H. and Levine, H. D. (1949). Myocarditis in vitamin E-deficient rabbits. *Amer. J. Pathol.*, **25,** 265.
Braude, R., Kon, S. K. and Porter, J. W. G. (1953). Antibiotics in nutrition. *Nutrition Absts. Revs.*, **23,** 473.
Brody, S. (1935). The relation between feeding standards and basal metabolism. *Rep. of Conference on Energy Metabolism held at State Coll., Pennsylvania, June 1935*, p. 12.
Brozzetti, P. (1941). [Hay meal in the feeding of rabbits.] *Riv. Zootec.*, **18,** 49.
Bruce, H. M. (1947). Feeding and breeding of laboratory animals. 4. Breeding of rabbits without fresh green food. *J. Hyg.*, **45,** 169.
Bruce, H. M. and Parkes, A. S. (1946). Feeding and breeding of laboratory animals. 2. Growth and maintenance of rabbits without fresh green food. *J. Hyg.*, **44,** 501.
Brüggemann, H. (1937). [Utilisation of food by rabbits. Basis of modern rabbit feeding.] *Biedermanns Zentralbl. B. Tierernährung*, **9,** 374.
Butterfield, H. M. (1929). *Amer. Rabbit Rec.*, October 3.
Butterfield, H. M. and Lloyd, W. E. (1935). Rabbit raising. *California Exten. Agric. Serv. Circular* No. 9, Revised edition, p. 38.

Cahn, T. and Houget, J. (1952*a*). [Effect of feeding on respiratory exchange in the rabbit.] *J. Physiol., Paris*, **44,** 115.
Cahn, T. and Houget, J. (1952*b*). [Stimulation of metabolism in the rabbit by food and reservations to the theory of specific dynamic action in this species.] *C.R. Acad. Sci.*, **234,** 465.
Cahn, T. and Houget, J. (1953). [Regulation of daily energy expenditure in the rabbit.] *J. Physiol., Paris*, **45,** 67.
Cahn, T. and Houget, J. (1960). [Metabolic reactions after taking food in the rabbit. The causes of specific dynamic action.] *Arch. Sci. physiol.*, **14,** 279.
Casady, R. B. (1961). Private communication.
Casady, R. B. and Gildow, E. M. (1959). Rabbit nutrition. *Proc. Animal Care Panel* **9** (1) March.
Cavanagh, J. B. and MacDonald, I. (1958). An experimental nutritional myopathy and neuropathy. *Quart. J. Exp. Physiol.*, **43,** 235.
Chatfield, C. and Adams, G. (1940). Proximate composition of American food materials. *U.S. Dept. Agric. Circular* No. 549.
Chevrel, M. L. and Cormier, M. (1948*a*). [Effect of vitamin A deficiency on the genital system of the male rabbit.] *C.R. Acad. Sci.*, **226,** 1854.
Chevrel, M. L. and Cormier, M. (1948*b*). [Effect of vitamin E deficiency on the genital system of the male rabbit.] *C.R. Acad. Sci.*, **226,** 2013.
Chevrel, M. L. and Cormier, M. (1948*c*). [Interdependence of the actions of vitamins A and E on the genital system of the male rabbit.] *C.R. Acad. Sci.*, **226,** 2179.
Christian, M. I. (1935–36). The importance of water in the diet of rabbits kept for experimental purposes. *Harper Adams Utility Poultry J., Rabbit Suppl.*, **21,** 539.
Clarke, E. M. W. (1961). Private communication.
Cook, G. A. (1932). Selective chewing of sodium treated posts by wild rabbits. *J. Counc. Sci. Indust. Res. Austral.*, **5,** 196.
Crampton, E. W., Campbell, J. A. and Lange, E. H. (1940). Pasture studies. 17. The relative ability of steers and rabbits to digest pasture herbage. *Sci. Agric.*, **20,** 504.
Crampton, E. W. and Finlayson, D. A. (1935). Pasture studies. 7. The effect of fertilization on the nutritive value of pasture grass. *Empire J. Exp. Agric.*, **3,** 331.
Crasemann, E. (1952). The energy effect of additional crude fibre to the rabbit. *Schweiz. Arch. Tierheilk.*, **94,** 731.

DAVIS, J. (1957). Some observations on lactation and food intakes in a colony of Chinchilla-Giganta rabbits. *J. Animal Technicians Assoc.*, **7**, 62.
DIEHL, J. F. (1960). Effects of hepatic coccidiosis infection in rabbits on tissue levels of vitamin A and vitamin E. *J. Nutrition*, **71**, 322.
DIEHL, J. F. AND KISTLER, B. G. (1961). Vitamin E saturation test in coccidiosis-infected rabbits. *J. Nutrition*, **74**, 495.
DONNELLY, E. D. AND HAWKINS, G. E. (1959). The effects of stem type on some feeding qualities of sericea lespedeza, *L. cuneata*, as indicated in a digestion trial with rabbits. *Agronom. J.*, **51**, 293.
DOWNS, A. W. (1936). The quantity of iodine in the thyroid gland of the rabbit and the influence thereon of a diet of cabbage. *J. Lab. Clin. Med.*, **22**, 270.
DRAPER, H. H. (1957). Ineffectiveness of selenium in the treatment of nutritional muscular dystrophy in the rabbit. *Nature*, **180**, 1419.
DUDLEY, F. J. AND WILSON, W. K. (1943). Carcass investigations with rabbits. Some observations on the weights of rabbits at time of killing. *J. Agric. Sci.*, **33**, 129.
DUNKEL, K. H. (1955). [Studies on the economic importance of vegetable waste in rabbit feeding with special reference to home supply.] *Arch. Geflügelzucht Kleintierk.*, **4**, 116.

EDEN, A. (1940). Coprophagy in the rabbit. *Nature*, **145**, 36; 628.
ELENEK, JA. (1954). [The effect of feeding silkworm pupae to rabbits on fertility and the growth and development of the young.] *Karakul. Zver.*, **7**, No. 6, 48.
ELLIS, G. H., MATRONE, G. AND MAYNARD, L. A. (1946). A 72 per cent H_2SO_4 method for the determination of lignin and its use in animal nutrition studies. *J. Animal Sci.*, **5**, 285.
ELLIS, G. H., SMITH, S. E. AND GATES, E. M. (1947). Further studies of manganese deficiency in the rabbit. *J. Nutrition*, **34**, 21.
EPPSTEIN, S. H. AND MORGULIS, S. (1940). Minimum daily requirement of rabbits for α-tocopherol. *Proc. Soc. Exp. Biol. Med.*, **45**, 715.
EPPSTEIN, S. H. AND MORGULIS, S. (1941). The minimum requirement of rabbits for *dl*-α-tocopherol. *J. Nutrition*, **22**, 415.
ERIKSSON, S. (1946). The value of metabolizable energy in maintenance at a variable percentage of crude fiber in the dry matter of rations. *Kungl. Lantbrukshögsk. Ann.*, **13**, 179.
ERIKSSON, S. (1952). Metabolism of rabbits at different levels of crude fiber and protein. *Kungl. Lantbrukshögsk. Ann.*, **19**, 7.

FANGAUF, R. AND DREYER, W. (1940). [Effect of protein supplements on rabbits.] *Arch. Kleintierzucht*, **1**, 69.
FANGAUF, R. AND IMMENKAMP, G. (1938). [Food consumption and weight increase in rabbits; comparison of various breeds.] *Arch. Geflügelk.*, **12**, 185.
FEASTER, J. P. AND DAVIS, G. K. (1959). Sulphate metabolism in rabbits on high molybdenum intake. *J. Nutrition*, **67**, 319.
FRANK, I., HADELER, U. AND HARDER, W. (1951). [Nutritional physiology of rodents. The significance of coprophagy and the composition of the faeces eaten.] *Pflügers Arch.*, **253**, 173.

GASNIER, A., ARCHAMBAUD, J. AND LEROY, A. M. (1941). [Nutritive value for rabbits of crushed bran and lucerne.] *C.R. Acad. Agric.*, December.
GASNIER, A., GOMPEL, M., HAMON, F. AND MAYER, A. (1932). [Automatic regulation of food intake and absorption as a function of the water content of the diet.] *Ann. Physiol. Physicochim. biol.*, **8**, 870.
GERI, G. (1958). [Studies on the feeding and productivity of the rabbit.] *Ann. Sper. agrar.*, **12**, 1045.
GHONEIM, A., ABOU-RAYA, A. K. AND EL-ABBADY, M. R. (1958). Meat production with Baladi rabbits fed on clover (Trifolium alexandrinum). *Cairo Univ. Fac. Agric. Bull.* No. 166, January 1958 (1959).
GLOVER, J. AND DUTHIE, D. W. (1958). The apparent digestibility of crude protein by non-ruminants and ruminants. *J. Agric. Sci.*, **51**, 289.

Goettsch, M. and Pappenheimer, A. M. (1931). Nutritional muscular dystrophy in the guinea-pig and rabbit. *J. Exp. Med.*, **54**, 145.
Goldblatt, H. and Moritz, A. R. (1925). Experimental rickets in rabbits. *J. Exp. Med.*, **42**, 499.
Gompel, M., Hamon, F. and Mayer, A. (1936). [Effect of sodium chloride content of the ration on the feeding habits of the domesticated rabbit.] *Ann. Physiol. Physicochim. biol.*, **12**, 504.
Grünigen, F. v. (1933). [Significance for rabbits of the nutritive ratio of the diet.] *Die Tierwelt*, **43**, 1198; 1221; 1259; 1318; 1346.

Hagelin, K. F. (1935). *Kött och Pälskaniner Handbok i Rationell Uppfödning* [Meat and fur rabbits. Handbook of rational feeding.] Stockholm, Kooperativa Förbundets Bokförlag.
Hammond, J. (1931). Rabbits. *Year Book of the National Rabbit Council, Edinburgh.*
Hammond, J. (1936). Pregnancy in the rabbit. *6. Weltgeflügelkongress, Berlin-Leipzig*, i, 153.
Hammond, J. and Marshall, F. H. A. (1925). *Reproduction in the rabbit.* Oliver and Boyd, Edinburgh.
Handler, P. (1944). The effect of excessive nicotinamide feeding on rabbits and guinea pigs. *J. Biol. Chem.*, **154**, 203.
Hankins, O. G., Hiner, R. L., Templeton, G. S. and Kellogg, C. E. (1960). Physical composition of fryer rabbits of prime, choice and commercial grades. *U.S. Dept. Agric., Agric. Res. Serv., Animal Husb. Res. Div., A. H. Correspondence Aid* No. 37.
Haring, F. and Gruhn, R. (1951). [Growth in size as a measure of rhythm of growth, feed consumption and slaughter value, studied with rabbit races of different sizes. 1.] *Arch. Tierernährung*, **2**, 177.
Harris, L. J., Constable, B. J., Howard, A. N. and Leader, A. (1956). Vitamin C economy of rabbits. *Brit. J. Nutrition*, **10**, 373.
Hart, E. B., Steenbock, H., Elvehjem, C. A. and Waddell, J. (1925). Iron in nutrition. 1. Nutritional anemia on whole milk diets and the utilization of inorganic iron in hemoglobin building. *J. Biol. Chem.*, **65**, 67.
Hawkins, G. E. (1957). Use of the rabbit as a pilot animal in forage research. *Proc. Assoc. Southern Agricultural Workers, 54th Annu. Convention, Birmingham, Ala., February.*
Heinemann, W. W., Ensminger, M. E., Ham, W. E. and Oldfield, J. E. (1957). The effects of phosphate fertilization of alfalfa on growth, reproduction and body composition of domestic rabbits. *J. Animal Sci.*, **16**, 467.
Hellberg, A. (1949). Metabolism of rabbits at different planes of nutrition. (Including the influence of the duration of fast and the degree of fatness.) *Thesis, Univ. Uppsala.* Almquist and Wiksells.
Heller, V. G., Wall, R. and Briggs, H. M. (1941). The utilization of feed as affected by grinding. *Oklahoma Agric. Exp. Stat. Tech. Bull.* No. 10.
Hetler, R. A. (1934). The development of xerophthalmia and the keratinization of epithelial tissue on withdrawal of vitamin A from the diet of the monkey (*Macacus rhesus*), guinea pig, rabbit, and adult albino rat. *J. Nutrition*, **8**, 75.
Hill, L. (1920). The science of ventilation and open air treatment. Part II. *M.R.C. Spec. Rep. Ser.* No. 52, H.M.S.O., London.
Hills, D. M. and Macdonald, I. (1956). Hand-rearing of rabbits. *Nature*, **178**, 704.
Hirzel, R. (1935). Note on the effect of "condition" on the colour of body fat in rabbits. *J. Agric. Sci.*, **25**, 541.
Hofmann, F. and Steiner, K. (1959). [Effect of high-protein feeding on development of young rabbits of small, medium and large breeds.] *Arch. Geflügelzucht Kleintierk.*, **8**, 266.
Hogan, A. G. and Hamilton, J. W. (1942). Adequacy of simplified diets for guinea pigs and rabbits. *J. Nutrition*, **23**, 533.
Hogan, A. G. and Ritchie, W. S. (1934). Nutritional requirements of rabbits and guinea pigs. *Univ. Missouri Agric. Exp. Stat. Res. Bull.* No. 219.
Holley, K. T. *et al.* (1955). Cited by Casady and Gildow (1959).

Homutova, M. A. (1957). [The effect of a trace element mixture on animals.] *Vop. Pitan.*, **16**, No. 3, 47.
Hove, E. L. and Copeland, D. H. (1954). Progressive muscular dystrophy in rabbits as a result of chronic choline deficiency. *J. Nutrition*, **53**, 391.
Hove, E. L., Copeland, D. H., Herndon, J. F. and Salmon, W. D. (1957). Further studies on choline deficiency and muscular dystrophy in rabbits. *J. Nutrition*, **63**, 289.
Hove, E. L., Copeland, D. H. and Salmon, W. D. (1954). Choline deficiency in the rabbit. *J. Nutrition*, **53**, 377.
Hove, E. L. and Herndon, J. F. (1955). Potassium deficiency in the rabbit as a cause of muscular dystrophy. *J. Nutrition*, **55**, 363.
Hove, E. L. and Herndon, J. F. (1957*a*). Vitamin B_6 deficiency in rabbits. *J. Nutrition*, **61**, 127.
Hove, E. L. and Herndon, J. F. (1957*b*). Growth of rabbits on purified diets. *J. Nutrition*, **63**, 193.
Huang, T. C., Ulrich, H. E. and McCay, C. M. (1954). Antibiotics, growth, food utilization and the use of chromic oxide in studies with rabbits. *J. Nutrition*, **54**, 621.
Hutchinson, J. C. D. (1947). Nutrition of domestic rabbits. 1. The effect of nutrition on the carcass composition of the rabbit. 2. The efficiency of rabbit-meat production from weeds, fed alone and with cooked potatoes. *Brit. J. Nutrition*, **1**, 219; 231.

Innes, J. R. M. and Yevich, P. P. (1954). So-called nutritional muscular dystrophy as a cause of "paralysis" in rabbits. *Amer. J. Pathol.*, **30**, 555.

Jaffé, W. G. (1950). [Toxicity of raw beans for rabbits.] *Acta científ. venezol.* **1**, 16.
Jarl, F. (1944). [Digestibility experiments with rabbits.] *Lantbrukshögsk. Husdjursförsöksanst. Medd.*, No. 16.
Jarl, F. (1948). [Importance of vitamin D in feeding rabbits.] *Lantbrukshögsk. Husdjursförsöksanst. Medd.*, No. 29.
Jespersen, J. and Olsen, H. M. (1942). [Feeding experiments with rabbits.] *Beretn. Forsøgslab. København*, No. 203.
Johnson, H. D., Cheng, C. S. and Ragsdale, A. C. (1957). Environmental physiology and shelter engineering, with special reference to domestic animals. 46. Comparison of the effect of environmental temperature on rabbits and cattle. 2. Influence of rising environmental temperature on the physiological reactions of rabbits and cattle. *Missouri Agric. Exp. Stat. Res. Bull.* No. 648.
Johnson, H. D., Ragsdale, A. C. and Cheng, C. S. (1957). Environmental physiology and shelter engineering, with special reference to domestic animals. 45. Comparison of the effects of environmental temperatures on rabbits and cattle. 1. Influence of constant environmental temperature (50° and 80°F) on the growth responses and physiological reactions of rabbits and cattle. *Missouri Agric. Exp. Stat. Res. Bull.* No. 646.

Kalniņš, V. (1946). [The vitamin C requirement of the rabbit.] *Upsala Läkarefören. Förhandl.*, **51**, 215.
Kellogg, C. E. and Templeton, G. S. (1948). Effect of various factors on grades of New Zealand White rabbitskins. *U.S. Dept. Agric. Circular* No. 789.
Kellogg, C. E., Templeton, G. S. and Suitor, A. (1949). Feed required to produce 6-pound rabbits after weaning and conditions affecting their carcass grades and cuts. *U.S. Dept. Agric. Circular* No. 819.
Kendall, K. A., Hays, R. L. and Rolleri, G. D. (1954). Impaired reproduction in the rabbit fed supplemented diets containing soybean hay. *J. Animal Sci.*, **13**, 859.
Kendall, K. A., Salisbury, G. W. and Vandemark, N. L. (1950). Sterility in the rabbit associated with soybean hay feeding. *J. Nutrition*, **42**, 487.
Kennaway, E. L. (1943). The supply of water to rabbits and guinea pigs. *Brit. Med. J.*, i, 760.

Kivman, G. Ja., Čumačenko, N. V., Smol'nikova, N. M., Mitrofanov, V. S. and Ruhadze, E. Z. (1959). [Hypersensitivity of rabbits to tetracyclines.] *Bjull. ėksp. Biol. Med.*, No. 10, 52.

König, J. (1919). *Chemie der menschlichen Nahrungs- und Genussmittel*, Vol. 1A, p. 396. [Chemistry of human foods.] Springer, Berlin.

Kulwich, R., Pearson, P. B. and Lankenau, A. H. (1954). Effect of coprophagy upon S^{35} uptake by rabbits after ingestion of labeled sodium sulfate. *Arch. Biochem.*, **50**, 180.

Kulwich, R., Struglia, L., Jackson, J. T. and Pearson, P. B. (1954). Synthesis of cystine and methionine from S^{35}-labeled sodium sulfate in the rabbit. *Federation Proc.*, **13**, 463.

Kulwich, R., Struglia, L. and Pearson, P. B. (1953). The effect of coprophagy on the excretion of B vitamins by the rabbit. *J. Nutrition*, **49**, 639.

Kunkel, H. O. and Pearson, P. B. (1948). Magnesium in the nutrition of the rabbit. *J. Nutrition*, **36**, 657.

Kurilov, N. V., Gorškov, Ju. I. and Mašurko, M. I. (1958). [Effect of biomycin on the fertility of does and the development of young rabbits.] *Vestn. sel'skohoz. Nauki*, No. 10, 56.

Kurilov, N. V., Lipatova, N. A. and Mašurko, M. I. (1958). [Influence of antibiotics on growth of young rabbits and their resistance to disease.] *Krolik. Zver.*, **1**, No. 4, 27.

Lamming, G. E., Salisbury, G. W., Hays, R. L. and Kendall, K. A. (1954). The effect of incipient vitamin A deficiency on reproduction in the rabbit. 1. Decidua, ova and fertilization. 2. Embryonic and fetal development. *J. Nutrition*, **52**, 217; 227.

Lamming, G. E., Woollam, D. H. M. and Millen, J. W. (1954). Hydrocephalus in young rabbits associated with maternal vitamin A deficiency. *Brit. J. Nutrition*, **8**, 363.

Lawrence, J. M. and McGinnis, J. (1952). The effect of terramycin on the growth of rabbits. *Arch. Biochem. Biophys.*, **37**, 164.

Lee, R. C. (1939*a*). Basal metabolism of the adult rabbit and prerequisites for its measurement. *J. Nutrition*, **18**, 473.

Lee, R. C. (1939*b*). Size and basal metabolism of the adult rabbit. *J. Nutrition*, **18**, 489.

Lee, R. C. (1942). Heat production of the rabbit at 24°C as affected by previous adaptation to temperatures between 10° and 31°C. *J. Nutrition*, **23**, 83.

Leitch, I. and Godden, W. (1941). The efficiency of farm animals in the conversion of feedingstuffs to food for man. *Imperial Bur. Animal Nutrit. Tech. Commun.* No. 14.

Light, R. F. and Frey, C. N. (1941). Bone fractures due to low calcium diets. *Proc. Soc. Exp. Biol. Med.*, **48**, 256.

Lintzel, W. and Radeff, T. (1931). [Iron content and iron assimilation of newborn and sucking animals (experiments on rabbits, guineapigs, rats, dogs, cats, pigs, goats and cattle).] *Arch. Tierz. Tierernährung*, **6**, 313.

Lorenzen, E. J. and Smith, S. E. (1947). Copper and manganese storage in the rat, rabbit and guinea pig. *J. Nutrition*, **33**, 143.

Mackenzie, C. G. (1942). Cure of repeated attacks of nutritional muscular dystrophy in the rabbit by alpha-tocopherol. *Proc. Soc. Exp. Biol. Med.*, **49**, 313.

Mackenzie, C. G., Levine, M. D. and McCollum, E. V. (1940). The prevention and cure of nutritional muscular dystrophy in the rabbit by alpha-tocopherol in the absence of a water-soluble factor. *J. Nutrition*, **20**, 399.

Mackenzie, C. G., Mackenzie, J. B. and McCollum, E. V. (1941). Uncomplicated vitamin E deficiency in the rabbit and its relation to the toxicity of cod liver oil. *J. Nutrition*, **21**, 225.

Mackenzie, C. G. and McCollum, E. V. (1939). Vitamin E and nutritional muscular dystrophy. *Science*, **89**, 370.

Mackenzie, C. G. and McCollum, E. V. (1940). The cure of nutritional muscular dystrophy in the rabbit by alpha-tocopherol and its effect on creatine metabolism. *J. Nutrition*, **19**, 345.

MADSEN, H. (1939). Does the rabbit chew the cud? *Nature*, **143,** 981.
MADSEN, L. L. (1936). The comparative effects of cod liver oil, cod liver oil concentrate, lard and cottonseed oil in a synthetic diet on the development of nutritional muscular dystrophy. *J. Nutrition*, **11,** 471.
MAGEE, A. C. AND MATRONE, G. (1958). Estrogenic activity of soybean forage. *J. Animal Sci.*, **17,** 787.
MAIOCCO, F. (1936). [Influence of vitamin E on the productiveness of rabbits.] *6. Weltgeflügelkongress, Berlin-Leipzig*, ii, 251.
MANGOLD, E., COLUMBUS, A. AND HOCK, A. (1937). [Effect of sawdust on the course of digestion and on the digestibility of feeds in rabbits.] *Arch. Geflügelk.*, **11,** 305.
MANN, I., PIRIE, A., TANSLEY, K. AND WOOD, C. (1946). Some effects of vitamin A deficiency on the eye of the rabbit. *Amer. J. Ophthalmol.*, **29,** 801.
MATRONE, G., HARTMAN, R. H. AND CLAWSON, A. J. (1959). Studies of a manganese-iron antagonism in the nutrition of rabbits and baby pigs. *J. Nutrition*, **67,** 309.
MATRONE, G., WELDON, V. B., SMART, W. W. G. (JR.), SHERWOOD, F. W., SMITH, F. H. AND WISE, G. H. (1954). Effects of phosphate fertilization and dietary mineral supplements on the nutritive value of soybean forage. *J. Nutrition*, **52,** 127.
MATTILL, H. A. AND GOLUMBIC, C. (1942). Vitamin E, cod liver oil and muscular dystrophy. *J. Nutrition*, **23,** 625.
MCCARRISON, R., SANKARAN, G. AND MADHAVA, K. B. (1933). Effect of an exclusive diet of cabbage on the internal organs of rabbits. *Ind. J. Med. Res.*, **20,** 723.
MCCAY, C. M., MADSEN, L. L. AND MAYNARD, L. A. (1933). Further studies of synthetic diets for herbivora. *J. Biol. Chem.*, **100,** lxviii.
MCMILLIN, H. R. (1931). Composition of rabbit meat. *J. Home Econ.*, **23,** 1149.
MELLANBY, E. (1934). Xerophthalmia, trigeminal degeneration and vitamin A deficiency. *J. Pathol. Bacteriol.*, **38,** 391.
MELLANBY, E. (1935). Lesions of the central and peripheral nervous systems produced in young rabbits by vitamin A deficiency and a high cereal intake. *Brain*, **58,** 141.
MELLANBY, M. AND KILLICK, E. M. (1926). A preliminary study of factors influencing calcification processes in the rabbit. *Biochem. J.*, **20,** 902.
MENZIES, W. (1959). The effect of weaning age on weight gain in rabbits. *J. Animal Technicians Assoc.*, **9,** 59.
MERRILL, A. L. AND WATT, B. K. (1955). Energy value of foods—basis and derivation. *U.S. Dept. Agric., Agric. Handbook* No. 74.
MEUNIER, P., VINET, A. AND JOUANNETEAU, J. (1947). [Antagonistic effects of vitamin E and fish liver oils on the growth of the rabbit.] *Bull. Soc. Chim. biol.*, **29,** 507.
MILLEN, J. W. AND WOOLLAM, D. H. M. (1956). The effect of the duration of vitamin-A deficiency in female rabbits upon the incidence of hydrocephalus in their young. *J. Neurol. Neurosurg. Psychiat.*, **19,** 17.
MILLEN, J. W., WOOLLAM, D. H. M. AND LAMMING, G. E. (1953). Hydrocephalus associated with deficiency of vitamin A. *Lancet*, **265,** 1234.
MILLEN, J. W., WOOLLAM, D. H. M. AND LAMMING, G. E. (1954). Congenital hydrocephalus due to experimental hypovitaminosis A. *Lancet*, **267,** 679.
MILLER, W. J., WAUGH, R. K. AND MATRONE, G. (1954). Comparison of the digestibility of certain pasture forages in the fresh and dried states. *J. Animal Sci.*, **13,** 283.
MILMAN, A. E. AND MILHORAT, A. T. (1953). Metabolic patterns in experimentally induced muscular dystrophy. *Proc. Soc. Exp. Biol. Med.*, **84,** 654.
MOORE, R. A., BITTENGER, I., MILLER, M. L. AND HELLMAN, L. M. (1942). Abortion in rabbits fed a vitamin K deficient diet. *Amer. J. Obstet. Gynecol.*, **43,** 1007.
MORGULIS, S. AND SPENCER, H. C. (1936). A study of the dietary factors concerned in nutritional muscular dystrophy. 1. Causation and prevention of nutritional muscular dystrophy. *J. Nutrition*, **11,** 573.

Morimoto, H. and Kameoka, K. (1952). [Studies on the feeding standard of rabbits. 1. Protein and nutrient requirement for the maintenance of adult rabbits.] *Bull. Nat. Inst. Agric. Sci., Yahagi (G)*, No. **4**, 113.
Moritz, A. R. and Krenz, C. (1930). The relation of the fat-soluble vitamins (A and D) to the development of experimental rickets in rabbits. *J. Nutrition*, **2**, 257.
Morot, C. (1882). *Mem. Soc. centr. med. vet.*, **12**, Ser. 1. (Cited by Madsen 1939).
Morris, S. (1936). The protein requirements of lactation. *Nutrition Absts. Revs.*, **6**, 273.
Morris, S. G. (1939). Synthetic alpha-tocopherol and nutritional muscular dystrophy. *Science*, **90**, 424.

Nachtsheim, H. (1931). [Influence of nutrition on the development of litter mates showing inherited differences.] *Proc. Internat. Conf. Rabbit Breeders, Internat. Furrier's Exhibition, Leipzig.*
National Research Council, Committee on Animal Nutrition, U.S.A. (1954). Nutrient requirements for domestic animals. 9. Nutrient requirements for rabbits. *Nat. Acad. Sci.—Nat. Res. Counc., Washington, Publ.* No. 331.
National Research Council, Committee on Animal Nutrition, U.S.A. and National Advisory Committee on Agricultural Services, Committee on Animal Nutrition, Canada. (1959). Joint United States–Canadian Tables of Feed Composition. *Nat. Acad. Sci.–Nat. Res. Counc., Washington, Publ.* No. 659.
Nehring, K., Hoffmann, L. and Schiemann, R. (1959). [The utilisation of energy in feed in relation to plane of nutrition. 1. Experiments with rabbits and rats.] *Arch. Tierernährung*, **9**, 85.
Nehring, K. and Schramm, W. (1939). [Utilisation of various feedingstuffs by the rabbit. A. Comparative studies with wethers and pigs.] *Biedermanns Zentralbl. B. Tierernährung*, **11**, 301.
Nelson, V. E. and Lamb, A. R. (1920). The vitamin requirement of various species of animals. 1. The production of xerophthalmia in the rabbit. *Amer. J. Physiol.*, **51**, 530.
Nelson, V. E., Lamb, A. R. and Heller, V. G. (1922*a*). The effect of vitamin deficiency on various species of animals. *Amer. J. Physiol.*, **59**, 335.
Nelson, V. E., Lamb, A. R. and Heller, V. G. (1922*b*). The vitamin requirement of various species of animals. 3. The production and cure of xerophthalmia in the suckling. *Amer. J. Dis. Child.*, **23**, 518.
Neseni, R. and Scheven, B. (1958). [Feeding trials with rabbits on differently preserved green fodders.] *Arch. Geflügelzucht Kleintierk.*, **7**, 103.
Neumeister, H. and Krause, B. (1956). [Nutrient content of rabbit's milk.] *Arch. Geflügelzucht Kleintierk.*, **5**, 199.
Nickisch, K. (1950). [Digestibility of some feedingstuffs by the rabbit (beet seed, lime leaves, rape-, linseed-, mustard seed cake meals and burdock seed meal).] *Arch. Tierernährung*, **1**, 73.
Nickisch, K. (1952). [Digestibility of sunflower seeds and extracted sunflower seed meal by rabbits and ruminants.] *Arch. Tierernährung*, **3**, 48.
Niehaus, H. (1953). [Breeding and maintenance of Angora rabbits.] *Celler Jahrbuch*, **2**, 168.
Nielsen, J., Jensen, N. E. and Hansen, H. (1958). [7th Report from the rabbit progency testing station on Favrholm for the years 1955–56 and 1956–57.] *Beretn. Forsøgslab. København*, No. 307.
Nikitin, F. P. and Lipatova, N. A. (1956). [The possibility of reducing the amount of concentrates in the rations of rabbits.] *Karakul. Zver.*, **9**, No. 1, 34.

Olcese, O. and Pearson, P. B. (1948). Value of urea in the diet of rabbits. *Proc. Soc. Exp. Biol. Med.*, **69**, 377.
Olcese, O., Pearson, P. B. and Schweigert, B. S. (1948). The synthesis of certain B vitamins by the rabbit. *J. Nutrition*, **35**, 577.
Olcese, O., Pearson, P. B. and Sparks, P. (1949). Intestinal synthesis of niacin and the metabolic interrelationship of tryptophan and niacin in the rabbit. *J. Nutrition*, **39**, 93.

PAGE, D. (1942). Rabbit-feeding in war time. *Empire J. Exp. Agric.*, **10**, 103.
PAPPENHEIMER, A. M. (1948). *On certain aspects of vitamin E deficiency*. Charles C. Thomas, Springfield, Ill.
PASSMORE, R. (1935). A note on a synthetic diet for rabbits. *Biochem. J.*, **29**, 2469.
PERLMAN, H. B. AND WILLARD, J. (1941). The ear in experimental vitamin A deficiency. *Ann. Otol. Rhinol. Laryngol.*, **50**, 349.
PHILLIPS, P. H. AND BOHSTEDT, G. (1938). Studies on the effects of a bovine blindness-producing ration upon rabbits. *J. Nutrition*, **15**, 309.
PICKARD, J. N. (1928). The influence of certain foods on the wool growth of Angora rabbits. *Scot. J. Agric.*, **11**, 344.
PICKARD, J. N. (1928–29*a*). Studies on the wool production of Angora rabbits. *Harper Adams Utility Poultry J.*, **14**, No. 1, 8.
PICKARD, J. N. (1928–29*b*). The observed effects of the addition of cod liver oil and minerals to the diet on the wool yield of Angora rabbits. *Harper Adams Utility Poultry J.*, **14**, No. 9, 420.
PICKARD, J. N. (1931). [Production of Angora rabbits and their wool in England.] *Riv. Coniglicoltura*, **3**, No. 11, 9.
PICKARD, J. N. (1941). *Rabbits 1941*. British Rabbit Council.
PIRIE, A. AND WOOD, C. (1946). Effects of vitamin A deficiency in the rabbit. 1. On vitamin C metabolism. 2. On power to use preformed vitamin A. *Biochem. J.*, **40**, 557.
POPOV, N. F., KURILOV, N. V. AND NOVIKOV, V. K. (1957). [Diethylstilboestrol for increasing productivity of rabbits.] *Vestn. sel'skohoz. Nauki*, **2**, No. 12, 117.
PRJANISCHNIKOW, N. D. AND TOMME, M. F. (1936). [Effect of lignin on digestibility of rye straw.] *Biedermanns Zentralbl. B. Tierernährung*, **8**, 104.

RANDOIN, L. AND CAUSERET, J. (1950). [Intestinal microflora and excess of the pellagra-preventing vitamin in the rabbit.] *C.R. Acad. Sci.*, **231**, 369.
RAO, M. V. R. (1936). Studies on vitamin A deficiency. 1. Xerophthalmia and trigeminal nerve degeneration. *Indian J. Med. Res.*, **24**, 439.
RICHTER, K. AND HUNDT, K. W. (1934). [Effect of diet on the development and wool yield of Angora rabbits.] *Deutsch. landw. Tierzucht*, **38**, 208.
ROMANOVSKII, D. M. (1954). [Rabbit rearing (from experience of the Scientific Research Institute of Rabbit and Animal Rearing).] *Priroda*, No. 5, 56.
ROSAHN, P. D., GREENE, H. S. N. AND HU, C.-K. (1935). Observations on the gestation period of the rabbit. *J. Exp. Zool.*, **72**, 195.
ROSENTHAL, H. L. AND CRAVITZ, L. (1958). Organ, urine and feces vitamin B_{12} content of normal and starved rabbits. *J. Nutrition*, **64**, 281.
ROTH, H. (1960). [Manganese deficiency diseases of plants and animals.] *Biochem. Ztschr.*, **333**, 361.

SANDFORD, J. C. (1957). *The Domestic Rabbit*. Crosby Lockwood & Son Ltd., London.
SCHEUNERT, A. AND ZIMMERMANN, K. (1952). [Bacterial synthesis in the caecum and coprophagy in the rabbit.] *Arch. Tierernährung*, **2**, 217.
SCHIOPPA, L. (1936). [Further experiments with vitamin E. 4. Effect on the fertility and birthweight of rabbits.] *Ztschr. Vitaminforsch.*, **5**, 22.
SCHÜRCH, A. (1949). [The theoretical background of rabbit feeding.] *Schweiz. landwirtsch. Monatshefte*, **17**, (reprint) pp. 27.
SHORT, D. J. (1960). Automatic rabbit battery. *J. Animal Technicians Assoc.*, **11**, 13.
SHORT, D. J. AND GAMMAGE, L. (1959). A new pelleted diet for rabbits and guinea pigs. *J. Animal Technicians Assoc.*, **9**, 62.
SIMPSON, R. E., SCHWEIGERT, B. S. AND PEARSON, P. B. (1949). Effect of succinylsulfathiazole on the urinary excretion of folic acid by the rabbit. *Proc. Soc. Exp. Biol. Med.*, **70**, 611.
SMITH, S. E., DONFFER, E. AND MATHIEU, L. G. (1960). Protein for growing-fattening rabbits. *Feed Age*, **10**, No. 7.
SMITH, S. E. AND ELLIS, G. H. (1947*a*). Copper deficiency in rabbits. Achromotrichia, alopecia and dermatosis. *Arch. Biochem.*, **15**, 81.

SMITH, S. E. AND ELLIS, G. H. (1947*b*). Studies of the manganese requirement of rabbits. *J. Nutrition*, **34**, 33.
SMITH, S. E., MEDLICOTT, M. AND ELLIS, G. H. (1944*a*). The blood picture of iron and copper deficiency anemias in the rabbit. *Amer. J. Physiol.*, **142**, 179.
SMITH, S. E., MEDLICOTT, M. AND ELLIS, G. H. (1944*b*). Manganese deficiency in the rabbit. *Arch. Biochem.*, **4**, 281.
SPRAY, C. M. AND WIDDOWSON, E. M. (1950). The effect of growth and development on the composition of mammals. *Brit. J. Nutrition*, **4**, 332.
STUTE, K. (1953). [Digestibility of artichoke leaves by Angora rabbits.] *Celler Jahrbuch*, **2**, 182.
SWAMINATHAN, M. (1942). The application of the cyanogen bromide test to a study of the metabolism of nicotinic acid in rabbits. *Indian J. Med. Res.*, **30**, 537.
SWAN, K. C. AND SALIT, P. W. (1941). Lens opacities associated with experimental calcium deficiency. *Amer. J. Ophthalmol.*, **24**, 611.

TACCI, M. (1952). [Nutritive requirements of rabbits and the computation of rations.] *Riv. Zootec.*, **25**, 29.
TAYLOR, E. L. (1939). Does the rabbit chew the cud? *Nature*, **143**, 982.
TAYLOR, E. L. (1940). The demonstration of a peculiar kind of coprophagy normally practised by the rabbit. *Vet. Rec.*, **52**, 259.
TEMPLETON, G. S. (1938). Salt requirements of rabbits. *U.S. Dept. Agric., Bur. Biol. Survey, Wildlife Res. and Management Leaflet* BS–102.
TEMPLETON, G. S. (1939). Feed requirements of rabbits. *Proc. 7th World's Poultry Congr., Cleveland, Ohio*, 468.
TEMPLETON, G. S. (1952). Effects of certain methods of feeding and managing rabbits in commercial fryer production. *U.S. Dept. Agric., Circular* No. 901.
TEMPLETON, G. S. (1953). Rabbit mucoid enteritis. *Small Stock*, March, A.2.
TEMPLETON, G. S. AND KELLOGG, C. E. (1959). Raising rabbits. *U.S. Dept. Agric., Farmers' Bull.* No. 2131.
THACKER, E. J. (1956). The dietary fat level in the nutrition of the rabbit. *J. Nutrition*, **58**, 243.
THACKER, E. J. AND BRANDT, C. S. (1955). Coprophagy in the rabbit. *J. Nutrition*, **55**, 375.
THOMPSON, J. F. AND ELLIS, G. H. (1947). Is cobalt a dietary essential for the rabbit? *J. Nutrition*, **34**, 121.
TOMME, M. AND LORIA, K. (1936). [Gas, material and energy exchange in fasting rabbits.] *Biedermanns Zentralbl. B. Tierernährung*, **8**, 87.
TSUNEISHI, M. (1959). [Influence of the administration of antibiotics on riboflavin contents in the digestive tract of rabbits. 1. Riboflavin contents in the digestive tract of healthy and riboflavin-deficient rabbits. 2. Riboflavin contents in the digestive tract of rabbits after the administration of antibiotics.] *Shikoku Acta med.*, **15**, 711; 714.
TURNER, W. A., MEIGS, E. B. AND CONVERSE, H. T. (1936). Toxic effect of cod liver oil in the ration of the rabbit and the calf. *J. Biol. Chem.*, **114**, civ.

VENGE, O. (1953). Studies of the maternal influence on the growth in rabbits. *Acta agric. scand.*, **3**, 243.
VIVANCO, F. (1941). [Cure of experimental muscular dystrophy by synthetic α-tocopherol.] *Rev. clín. española*, **3**, 433.
VOINOV, D. I. (1933). [Feeding rabbits with green feed.] Sel'hozgiz, 1933.
VORIS, LeR., MARCY, L. F., THACKER, E. J. AND WAINIO, W. W. (1940). Digestible nutrients of feeding stuffs for the domestic rabbit. *J. Agric. Res.*, **61**, 673.

WATSON, C. J. AND GODDEN, W. (1935). The comparative digestibility of artificially dried pasture herbage by sheep and rabbits. *Empire J. Exp. Agric.*, **3**, 346.
WATSON, S. J. AND HORTON, E. A. (1936). Technique of digestibility trials with sheep and its application to rabbits. *Empire J. Exp. Agric.*, **4**, 25.
WATT, B. K. AND MERRILL, A. L. (1950). Composition of foods. *U.S. Dept. Agric. Bur. Human Nutrit. Agric. Handbook* No. 8.
WENDT, G. v. (1931–32). Contribution to the theory of the nutrition of the rabbit. *Harper Adams Utility Poultry J.*, **17**, 72.

WIDDOWSON, E. M. (1950). Chemical composition of newly born mammals. *Nature*, **166**, 626.
WIESNER, E. (1952). [Rearing and feeding motherless suckling rabbits.] *Arch. Tierernährung*, **2**, 280.
WILLIMOTT, S. G. (1928). On the pigment of the fat of certain rabbits. *Biochem. J.*, **22**, 1057.
WILSON, W. K. (1927–28). Rabbit growth studies under commercial conditions. *Harper Adams Utility Poultry J.*, **13**, 581.
WILSON, W. K. (1928–29*a*). Feeding and growth of commercial rabbits. *Harper Adams Utility Poultry J.*, **14**, 172.
WILSON, W. K. (1928–29*b*). Feeding rabbits. *Harper Adams Utility Poultry J.* **14**, 313.
WILSON, W. K. (1928–29*c*). Feeding of restricted and unrestricted mash as part of the ration of growing commercial rabbits. *Harper Adams Utility Poultry J.*, **14**, 366.
WILSON, W. K. (1930). On rabbit nutrition and reference to work at Harper Adams College. *Verhandl. I. Internat. Kaninchenzüchter Kongresses, Leipzig*, 191.
WILSON, W. K. (1932). Rations and their costs. *Fur and Feather*, July 1st, 2.
WILSON, W. K. (1935). Incidence of rickets in rabbits. *Nature*, **136**, 434.
WILSON, W. K. (1954). Unpublished observations.
WILSON, W. K. (1959). Modern rabbit-keeping. *Minist. Agric. Fish. Food Bull.* No. 50, 6th ed., H.M.S.O., London.
WILSON, W. K. AND BOTHAM, G. H. (1933–34). Weight loss and chemical composition of rabbit carcasses. *Harper Adams Utility Poultry J.*, **19**, 441.
WILSON, W. K. AND DOWNHAM, K. D. (1932). A note on deaths in a stock of albino Angora rabbits receiving sugar beet tops in the ration. *Vet. J.*, **88**, 263.
WILSON, W. K. AND DUDLEY, F. J. (1946). Fat colour and fur colour in different varieties of rabbits. *J. Genetics*, **47**, 290.
WILSON, W. K. AND DUDLEY, F. J. (1952). The duration of gestation in rabbit breeds and crosses. *J. Genetics*, **50**, 384.
WILSON, W. K. AND MORRIS, S. (1932). Studies in the composition of rabbit carcasses. 1. White Angoras. *J. Agric. Sci.*, **22**, 453.
WIRTH. (1933). Rations in the breeding of the Angora rabbit. *Riv. Coniglicoltura*, **5**, No. 3, 17.
WOODMAN, H. E. (1947). The composition and nutritive value of feeding stuffs. *Minist. Agric. Fish. Bull.* No. 124, H.M.S.O., London.
WOODWARD, J. W. AND MCCAY, C. M. (1932). Synthetic diets for herbivora. *Proc. Soc. Exp. Biol. Med.*, **30**, 241.
WOOLEY, J. G. (1947). Niacin deficiency in rabbits and response to tryptophan and to niacin. *Proc. Soc. Exp. Biol. Med.*, **65**, 315.
WOOLEY, J. G. (1954). Growth of three- to four-week-old rabbits fed purified and stock rations. *J. Nutrition*, **52**, 39.
WOOLEY, J. G. AND MICKELSEN, O. (1954). Effect of potassium, sodium or calcium on the growth of young rabbits fed purified diets containing different levels of fat and protein. *J. Nutrition*, **52**, 591.
WOOLEY, J. G. AND SEBRELL, W. H. (1945). Niacin (nicotinic acid), an essential growth factor for rabbits fed a purified diet. *J. Nutrition*, **29**, 191.